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GENERAL SCIENCE QUARTERLY

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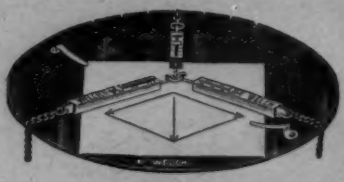

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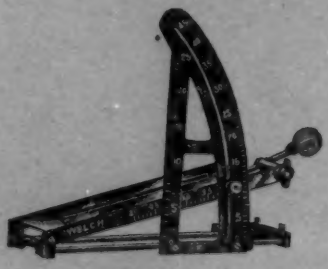

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The Need for Standards in Courses in the Teaching of General Science[1]

J. O. Frank
State Teachers College, Oshkosh, Wis.

There were offered during the year 1926-27, in the various colleges, normal schools, and universities of the United States, at least seventy different courses dealing with the Teaching of General Science. It is difficult to gather authentic information regarding the nature of some of these courses because some teachers do not care to give out information regarding the content of their courses. Fortunately, others gladly give such information. From outlines and other specific information furnished by teachers, from catalog descriptions, from direct observation, and from information furnished by teachers who have been students in the various courses, the nature of more than half of the courses offered, has been learned.[2]

Lack of Standardization of Courses

The outstanding fact about courses in the teaching of General Science, in the various teacher training institutions of the United States, is that these courses vary widely in about every way possible. Courses in the teaching of other high school sciences also tend to show individuality in many ways, but none exhibit the extreme variation shown by courses in the Teaching of General Science.

1 Read before the General Science Section of the Central Association of Science and Mathematics Teachers, at Detroit, November 25, 1927.

2 It should be said at this point that this study has been qualitative and not quantitative in nature. It is doubtful whether a quantitative study of science courses would disclose information of any great value. Nothing would be proved as to what should be done in science courses, by any facts as to what is done. For purposes of this paper, at least, no quantitative study is needed.

VARIATIONS SHOWN IN COURSES DEVOTED WHOLLY OR CHIEFLY TO THE TEACHING OF GENERAL SCIENCE

1. Time and Credit given:—
   (a) In regular semesters, 9, 12, or 18 weeks, two, three or five class periods per week, and carrying 2, 3, 4, or 5 credits.
   (b) In summer schools 4, 5, 6, 9, or 10 weeks, usually five class periods per week and carrying 2 or 3 credits.
2. Nature of Courses (Types of Courses):—
   (a) Review of the subject matter of General Science.
   (b) Review of subject matter, with some attention to methods.
   (c) (No subject matter.) Course devoted to aims, principles of selection and organization of subject matter, texts, tests, methods, etc.
   (d) The investigation of problems involved in the teaching of General Science, with methods of investigation stressed as much as the problems. (This type of course is given much less often than the other three, which are about equal in frequency.)
3. Names of Courses:—
   (a) "General Science for Teachers"
   (b) "The Teaching of General Science"
   (c) "Methods of Teaching General Science"
   (d) "The Teaching of Elementary Science"
   (e) "Principles of Science Teaching with Special Reference to General Science"
   (f) "Problems Involved in the Teaching of General Science"
4. Levels of Courses:—
   (a) Undergraduate.
   (b) Undergraduate and Graduate.
   (c) Graduate.
5. Departments Giving Courses:—
   (a) Education.
   (b) Biology.

(c) Chemistry.
(d) Physics.
(e) Agriculture.

6. Flexibility of Course:—
   (a) Entire course is set, "take it or leave it" type. Instructor has something he wants to give and he gives it.
   (b) Some flexibility to meet student needs.

7. Required Student Activities:—
   (a) Study of General Science texts.
   (b) Laboratory work in General Science.
   (c) Study of books on Science Teaching.
   (d) Reading periodicals and other literature on Science Teaching.
   (e) Special reports.
   (f) Term papers.
   (g) Listening to lectures.
   (h) Keeping notebooks.

   Each course requires some combination of these activities.

8. Qualifications of Teachers:—
   (a) Teachers with little or no experience in actual classroom, teaching of science. Persons strong in theories of education, but lacking in experience. Giving courses largely theoretical and of little practical value.
   (b) Teachers with many years of experience in teaching various high school sciences, including General Science, with little knowledge of the various educational theories and sometimes with much contempt for same.
   (c) Teachers with adequate training in both Education and Science, teachers who know science thoroughly and who know education just as thoroughly. Teachers with broad experience in Science Teaching.

THE BAD EFFECTS WHICH RESULT FROM THE LACK OF STANDARDIZATION OF COURSES IN THE TEACHING OF GENERAL SCIENCE

1. Teachers have difficulty in transferring credits for a course from one school to another, unless an outline of the course is furnished. Teachers may take two or even three entirely different courses under same name (The Teaching of Gen-

eral Science) or may have the same course under two different names.

2. A teacher may take a subject matter course and not go further because there is doubt about credit, or because of probability of duplication of work already done.
3. Teachers are frequently unable to tell from name and brief description of a course whether or not it offers further material worth while. A teacher may need subject matter and on entering a course get educational theory, or need information and instruction as to best educational theories and practices and get subject matter.
4. Having no standards to go by, teachers of these courses give whatever they happen to know best. Their students have been known to sit through weeks of lectures on subjects of no interest to them, so that later on in the course, they might get a few things which were of real value.
5. Because no college credit is given, teachers frequently fail to take much needed courses in subject matter.

The present lack of standardization of courses in the Teaching of General Science, results in discouragement and loss to teachers and prospective teachers of General Science. It will be a great advantage to them when a definite sequence of courses of rather well defined content based on the actual needs of teachers, is established. Then one of these courses may be taken in one university and the next in another without duplication or loss.

SUGGESTED REMEDIAL MEASURES

Much good would undoubtedly result if a definite sequence of courses of fairly definite content for teachers of General Science could be decided upon and recommended by a competent committee of qualified teachers. The report of such a committee would go far towards establishing standards in courses in the teaching of all the high school sciences, and would aid teachers in arranging a progressive program of study in preparation for the teaching of science. It would be difficult to persuade some schools that any subject matter course in General Science ought to carry college credit, but if all the facts were clearly shown, this would finally be accomplished.

It is suggested that three courses might form a sequence which could be made to cover all the fields now treated in the various undergraduate and graduate courses dealing with the teaching of General Science.

This sequence is offered as a basis of discussion and a point of departure in case a committee attempts to study needs and make recommendations.

A PROPOSED SEQUENCE OF COURSES

A. "Teachers Course in General Science."
An undergraduate course dealing with the broad general principles and the larger aspects of the subject matter of General Science. A course on the college level. 2 credits.

B. "The Teaching of General Science."
A course for graduates and undergraduates. Aims, selection and organization of subject matter, methods, text, tests, etc.
Prequisite: Course A, as described above or one year each of Physics, Biology, Chemistry, and Geology, or the equivalent. 2 credits.

C. "Methods of Investigation of Problems Involved in the Teaching of Science."
A strictly graduate course, dealing with methods of investigation and intended to find and train persons who have ability to contribute to science education.

OBJECTIVES AND CONTENTS OF THE COURSES RECOMMENDED ABOVE

A. TEACHERS COURSE IN GENERAL SCIENCE (A Subject Matter Course.)

The very fact that one-third if not one-half, of the courses for teachers of General Science, are courses which deal to a large extent with the subject matter of General Science, is strong evidence that there is a need for a Subject Matter Course, and no argument is being made here that such a course is not needed. On the other hand, the subject matter offered in many courses is plainly of secondary school level and it is difficult to see how college

credit can be given for it. Many schools absolutely refuse to give any credit for such a course.

It would seem that a subject matter course might be given on a college level. Many other secondary school subjects are treated again in college, the work being given on a higher plane, and no objections are heard.

There are *other excellent reasons* why a subject matter course ought to be available for teachers preparing to teach General Science.

1. We know that the average high school graduate still gets but a patchwork of science. The rather isolated bodies of scientific knowledge obtained in one, two or three units of science cover no complete or unified field. Certain fields of science are taboo and have not been touched. Such units as have been treated do not dovetail; they do not develop a useful understanding of the broad general principles of science. There are great gaps or holes, connecting fields which have not been touched. There has been no summarizing course to weld these units into a connected whole. The student still thinks in terms of the units of science rather than in science as a whole, in terms of *isolated experiences* rather than *broad general principles.*
2. There is still a great body of traditions, superstitions, and half truths, which is the heritage of every child who enters the public schools or has social contacts with the American public. Old ladies' tales, belief in luck, weather signs, foretelling future events, charms, magic cures for disease, and the like are quite common, and undoubtedly influence the events of everyday life.
3. Newspaper and magazine science with all its half truths and glaring inaccuracies, such as stories of men living in the age of the dinasaurs and accounts of the discoveries of "famous scientists" of whom no one has ever heard, is a potent factor in bringing to the young American student a mass of misinformation, which high school science seems unable to dispel.

It can safely be declared that the average high school graduate who is preparing to teach, is still a sceptic about many

important generalizations of science. What he has learned in high school, the things commonly believed by his parents and associates, and what he reads—do not agree. For some reason, he knows he has been left in almost complete ignorance about certain things,—but he has learned enough to know that he needs to learn more.

To fill in gaps in high school science, to treat important fields not treated in high school, to organize high school science as a whole, to clear away superstitions and beliefs in the pseudo science of newspapers and of tradition, and to dispel the scepticism of the average high school graduate—a unifying course in General Science on a college level is needed by every person who expects to be a teacher, and most especially by those who expect to teach science. Such a course is quite practicable and is already required in many schools, in curricula for the preparation of high school teachers.

OBJECTIVES OF A TEACHER'S COURSE IN GENERAL SCIENCE

A subject matter course. Not the details of the various topics of General Science, but the important generalizations of the various fields—especially of those fields not usually treated in the high school.

1. To bring prospective teachers up to a definite standard of understanding of science as an organized body of knowledge.
2. To develop orientation, perspective, and background founded on true science.
3. To clear away superstitions, traditional misbeliefs, and the pseudo science of the street.
4. To give actual information and instruction in important fields not covered by the high school sciences.
5. To give contacts with the best scientific books and periodical literature.
6. To further develop appreciation of the importance of scientific discoveries and of the works of the great scientists, and give confidence in science as a potent force in advancing human progress.
7. To give a preview and lay a foundation for the study of traditional sciences on a college level.
8. To develop new interests in science, especially in new fields of science.

9. To develop an understanding of the place of science in the future development of the resources and industries of the United States, and in national defense.
10. To give opportunity for questions in fields in which the student has so far dared not satisfy his curiosity.

TEACHER'S COURSE IN GENERAL SCIENCE

Some Suggested Units

1. The Place of the Earth in the Solar System.
2. The Solar System and the Universe.
3. Origin and Evolution of the Earth.
4. The Origin of Life.
5. The Origin and Evolution of Man.
6. Early Steps in Human Progress.
7. The Evolution of Society.
8. History of the Theories of Evolution.
9. Present Status of the Theory of Evolution.
10. Heredity and Eugenics.
11. The Control of Disease.
12. Modern Means of Communication.
13. Modern Transportation.
14. Science in Warfare.
15. Science as a Means of Progress.

B. THE TEACHING OF GENERAL SCIENCE.

Little need be said in argument for a course dealing with the methods and materials of General Science teaching. The evidence of a need for such a course is complete. The need is undisputed. There is, however, still great difference of opinion as to what ought to go into such a course. The course suggested here is based on reports gathered from more than two hundred science teachers. With the exception of subject matter, it deals with materials mentioned most often by teachers as their most difficult problems.

It must be admitted that General Science is still poorly taught in the average school. Frequently the legitimate objectives of the course are not accomplished at all. It is true that great progress has been made in the past five years. We have better texts, good courses of study have

been prepared, many teachers are coming to recognize the importance of General Science and to study the various aspects of general science teaching,—but the public, many administrative officials, and a large percentage of general science teachers still lack the spirit of the subject, they still are without the point of view and the philosophy of it they ought to have. The subject has a place of strategic importance in our scheme of secondary education and especially of science education. Here new study habits are being formed, new methods of problem solving are being learned, new attitudes established, new impressions of new fields being produced,—all this as in no other high school subject. In this scientific age these habits of study, these methods of problem solving, these impressions and attitudes are of extreme importance—we need our very best science teachers at this point.

A course for these teachers ought to deal with materials which will be of greatest immediate value in giving teachers the point of view of General Science, helping them to understand its place and importance in our scheme of education and bringing to them all possible aids to actual classroom instruction.

OBJECTIVES OF A COURSE IN THE TEACHING OF GENERAL SCIENCE

The value of a course in the teaching of general science must be measured in terms of the understandings, abilities, ideals, perspectives, attitudes, and the like it induces in the members of the course, and the desirable changes wrought in their teaching. The ultimate objectives are, then, the production of these ideals, abilities, attitudes, understandings, and the like. An analysis of the ultimate objectives seems to indicate the validity of a number of intermediate objectives, as follows:—

1. To give the orientation, perspective, and background required for an intelligent study of the problems involved in the teaching of general science.
2. To define the more important problems of general science teaching.

3. To describe and study the more fruitful methods of educational investigation and evaluate the usefulness of each in solving the problems of general science teaching.
4. To show the limited value of opinion, and to develop an appreciation of the permanent value of the findings of properly conducted research.
5. To open up new interests in the field of general science teaching.
6. To acquaint the student with, and interest him in, the more important literature relating to science teaching, and in the men and institutions which have produced it.
7. To present, discuss, and evaluate the current methods and plans for teaching general science.
8. To present and evaluate the various materials and devices used in teaching or enriching the course in general science, such as:— books and other literature; tests; apparatus; illustrative materials of all kinds, including slides and films; new experiments.
9. To present directly and in some detail tried methods of teaching some of the more difficult phases of general science.
10. To give direct information as to best practices, costs, methods of selection and purchase of supplies, and other similar topics relating to laboratory instruction and laboratory maintenance.
11. To give direct instruction in the technique and methods of experimental demonstration as applied to the teaching of general science.
12. To give direct advice and assistance to students who wish aid in the solution of their own teaching problems.
13. To give advice and assistance to each student who needs it, in determining the work for which he is best fitted, his needs in the way of professional training, and how to find and hold the position for which he is fitted.

OUTLINE OF PROPOSED COURSE IN THE TEACHING OF GENERAL SCIENCE

I. HISTORY OF SECONDARY EDUCATION IN THE UNITED STATES.

A. The early Latin Grammar Schools, the Academies, early High Schools. The Nature of these schools; what they contributed to the modern high school.

II. SCIENCE TEACHING IN THE HIGH SCHOOL.

A. In the first high schools.
B. Before the Civil War.
C. After the Civil War.
D. After 1872.
E. In 1900.

The nature of the subject-matter used; educational theories and practices of each period, remnants from these periods that are still with us, and how they influence present-day teaching.

III. THE STATUS OF THE SCIENCES IN PRESENT DAY HIGH SCHOOLS.

A. The junior high school sciences.
B. The senior high school sciences.
C. Standardizing agencies, what they are and how they influence science teaching.

IV. THE ORIGIN AND GROWTH OF GENERAL SCIENCE.

A. The early courses; their nature, texts used.
B. Growth in number and changes in type of courses. Evolution of general science texts.
C. The present status of general science. Types of courses.
D. Present practices in general science teaching.
E. Criticisms of general science.
F. Definition of the problems involved in teaching general science.

V. THE ROLE OF SCIENTIFIC INVESTIGATION IN PRESENT DAY EDUCATION.

A. The scientific attitude.
B. The scientific method.
D. Methods of investigation.
   1. Typical methods.
   2. Evaluation of methods.
   3. How to use them.

Not for the purpose of developing technique, but to give understanding and appreciation of methods of investigation, and confidence in their findings.

VI. THE AIMS OF SECONDARY EDUCATION AND THE ROLE OF GENERAL SCIENCE IN THEIR REALIZATION.

- A. The place and aims of science in the graded school, in the junior high school, and in the senior high school.
- B. Grade placement of each of the sciences in a twelve year program.

VII. THE SUBJECT MATTER OF GENERAL SCIENCE.

- A. Factors affecting the selection of subject matter.
- B. Principles underlying the selection and arrangement of subject matter.
  1. Consideration of the work of Hopkins, Bobbitt, Charters, Harap, and others.
- C. Principles of organization of subject matter.
- D. Examination of typical courses of study.

VIII. GENERAL SCIENCE TEXTS.

- A. The evaluation of texts on basis of general worth.
- B. Selecting texts to fit particular needs.

IX. METHODS OF TEACHING GENERAL SCIENCE.

- A. Evaluation of traditional methods.
- B. New methods.
- C. The laboratory method.
- D. The class demonstration.
- E. Combinations of methods into plans of instruction.
- F. A study of methods, plans of instruction and units of subject matter used by various cities.

X. WAYS AND MEANS OF ENRICHING THE GENERAL SCIENCE COURSE.

- A. Curricular materials.
- B. Extra-curricular materials.

XI. THE MEASUREMENT OF RESULTS.

- A. Kinds of tests and how to use them.
- B. A study of standardized tests. How they are made and used.

XII. THE GENERAL SCIENCE LABORATORY.

- A. Planning and equipping a laboratory.
- B. The selection and purchase of supplies and apparatus.

XIII. THE PROFESSIONAL PROBLEMS OF THE GENERAL SCIENCE TEACHER.

A. Job analysis of the work of the general science teacher.

B. Fundamentals in the curriculum for the training of general science teachers.

C. Getting and holding a position.

D. Keeping efficient.

C. METHODS OF INVESTIGATION OF PROBLEMS INVOLVED IN THE TEACHING OF SCIENCE.

This course would be intended for mature teachers who give promise of being able to make contributions to education. It would be for the purpose of giving an appreciation and an understanding of the methods of investigation, and to develop ability and technique in their use.

We have a right to expect teachers of General Science:—

(1) To know well the subject matter of General Science.

(2) To know how to teach General Science, to be able to teach it well, to have the proper point of view and the proper attitude towards the subject and to be able to accomplish the objectives of the subject. Not only this but to keep up-to-date in both science and education.

(3) When able to do so, to make contributions, however small, to the progress of education.

If we accept this point of view, we can see that an extended program of specialized study is necessary and the need for a standardized sequence of progressive courses of the type suggested, becomes quite clear.

Three Centuries of Natural Philosophy[1]

Founders' Day Address, Swarthmore College, on Oct. 29, 1927

W. F. G. Swann, D.Sc.,
Director, Bartol Research Foundation of The Franklin Institute.

Three thousand years ago there died in Egypt a king. He was buried with much pomp and ceremony, and in the company of such material things as reflected the atmosphere of his time. After thirty centuries, untouched except for the minor vandalism of robbers, these relics speak to us the story of an age which has passed. They tell us of a skill in craftmanship equal to our own, of a beauty in art and in concept of design such as wins the admiration of our most famous artists; and reading the evidence of a little act here and a little thought there, we begin to see a people such as we could well have known as friends,—a people of whom who can say that if one of them were born today and raised with our children he would be distinguishable from one of us. Yet, neither in the age that knew Tutankhamun, nor in any of the ancient civilizations that have gone before or after, do we find any shadow of a concept of that great scheme of nature's laws which has unfolded itself so unsparingly in our generation.

If the period from the dawn of history to the present time be shrunk into a day, we shall find that twenty-three hours of that day are barren as far as natural philosophy is concerned, for it is only in the last hour that science was born; and, even as the human child develops in its struggles toward manhood, so this child of nature has grown, but with such ever-increasing strength that in the last ten minutes of its existence, in the last twenty-five years of actual time, it has outshone all the accomplishments of its infancy and adolescence and has torn from nature more of her secrets than she has vouchsafed to man in the whole previous history of his existence.

Three hundred years ago we find the world just emerging from the state in which he who would search for the hidden truths of nature must contend with three great obstacles,—

1 Reprinted from Journal of the Franklin Institute of January, 1928.

superstition, the power of the church, and, last but not least, a conglomeration of fixed notions as to the way things should happen, built upon the pseudo-philosophic reasoning of bygone ages, reasoning founded not upon experimental bases, but upon dogma evolved out of the imaginations of the philosophers.

The train of scientific thought was founded largely upon the hypothesis that the writings of Aristotle were to be the ultimate court of appeal in all matters of dispute, and wondrous indeed were some of the things which Aristotle and his disciples had said. A good example of some of their misty philosophizing is the proof given by one of them that the world is perfect.

"The bodies of which the world is composed are solids and therefore have three dimensions. Now three is the most perfect number; for, of one we do not speak as a number, of two we say both; but three is the first number of which we say all. Moreover, it has a beginning, a middle, and an end."

Towards the end of the fifteenth century we find young Galileo enjoying the princely stipend of fifteen cents a day as professor of mathematics at the University of Pisa. It is true that the professor of medicine gets thirty times as much, and Galileo's parents had originally intended him to be a professor of medicine. But what does he care! For he is much interested in discovering the laws of falling bodies; and, in spite of the fact that Aristotle has said otherwise, he is contending that heavy bodies and light bodies fall at the same rate. In scientific circles much resentment is felt at such a revolutionary suggestion, for Aristotle, without appeal to experiment, has evolved out of the consciousness of his inner mind the decision that bodies fall at rates depending upon their weights. It matters not that young Galileo has ascended the leaning tower of Pisa with a one-pound weight and a hundred-pound weight and, in full view of the learned men of the day, has dropped them from the tower and found that they struck the ground together. For Aristotle has maintained otherwise, and science is the voice of Aristotle.

Neither is there more tolerance in the matter of astronomy. For Galileo has invented and constructed a telescope; and though he has received much honor from his university for this performance, and has had his salary doubled, there are many who not only refuse to accept what the telescope reveals,

but steadfastly refuse to look through it, lest they should be convinced of the truth of that which they do not wish to believe. With this obnoxious machine Galileo has found that the moon has mountains like the earth, which robs that body of some of its individual importance. He has found spots upon that most perfect of heavenly bodies, the sun; but worst of all, he says that Jupiter has four moons attendant upon him. This last conclusion is in a way to upset everything. Though too much of a man of progress to doubt the evidence of his own eyes, even the great Kepler is disturbed in his mind. For, according to all prevailing notions of the day, there should be seven planetary bodies and no more,—the earth, moon, Mercury, Venus, Mars, Jupiter and Saturn.

Hear the argument of Francesco Sizzi, himself a Florentine astronomer, against this assertion of Galileo:[2]

"There are seven windows in the head, two nostrils, two eyes, two ears, and a mouth; so, in the heavens there are two favorable stars, two unpropitious, two luminaries, and Mercury alone undecided and indifferent. From which, and many other similar phenomena of nature, such as the seven metals, etc., which it were tedious to enumerate, we gather that the number of planets is necessarily seven.

"Moreover, the satellites are invisible to the naked eye, and therefore can have no influence on the earth, and therefore are useless, and therefore do not exist.

"Besides, the Jews and other ancient nations, as well as modern Europeans, have adopted the division of the week into seven days, and have named them from the seven planets; now if we increase the number of planets this whole system falls to the ground."

You can judge of the wrath and indignation which Galileo brought upon his head when he contended in reply that, whatever might be the force of these arguments as a reason for believing beforehand that no more than seven planets would be discovered, they hardly seemed of sufficient weight to destroy the new ones when seen.

It was Galileo who wrested from nature the secret of the laws which govern motion—the laws which govern the motions

2 Quoted from Sir Oliver Lodge's "Pioneers of Science."

of almost everything, the planets in the heavens, the fly-wheel of the steam engine, the bird in flight—yes, and in a large measure, at any rate, the motions of the innermost parts of the very atoms of matter itself. But Galileo did not evolve these laws out of the dogmas of imagination, but by the more humble and safe appeal to direct experiment. He marked out the method of approach, the experimental method, which has been the model for all succeeding generations in their search for the fundamental facts which govern the workings of nature.

The laws of motion may be written on a postcard, but their consequences have not been exhausted in all the books men of science have written in three hundred years. As we all know, Galileo's life was beset with tribulation. He lived in an age when there was little tolerance for one who followed not the conventionalities of thought of the day. To question the learning of the past was arrogance, to discover new truth was blasphemy, and so he died, having sown, however, the seeds of the fruit that was to come. He died in a world seething with superstition and ruled by the dogmas of an ancient, past but a world which was destined only a year later to see the birth of one who is rated by many as the greatest genius of all time—that great prince of England's men of science—Isaac Newton.

In its purest aspect, the task of the natural philosopher today is to discover the relationships existing between the different phenomena which happen in our universe. He seeks to see in the workings of nature simply different illustrations of a few fundamental principles. Newton was the greatest of the pioneers in this method of systematized thought. In his great work, the "Principia," characterized by the Marquis Laplace as preeminent above all productions of the human intellect, he demonstrated the powerful simplicity of the fundamentals which control the destinies of the heavens. No longer did the universe appear as a bizarre and formless thing governed by such a heterogeneous system of agencies as to merit the caustic comment of the sovereign of Castile when, bewailing the complexities involved in an attempt to explain the motions of the planets, he remarked that "Were the heavens thus constituted, he could have given the Deity good advice."

No longer need the sun carry spokes, as Kepler thought, to grind the planets around in the heavens. No longer was a

guardian angel necessary for each planet to guide its course. No longer were the planets whirled through space by the whirlpools of an ether, as a twig is whirled about in the rapids. All that was necessary was the laws of motion of Galileo, operating under the influence of a force emanating from the sun according to the inverse square of the distance therefrom. And this force was no new and mysterious thing, for Newton showed that gravitation, that same old force which had been known for so long—gravitation, which causes apples to fall from the tree to the ground—was sufficient to control the moon in its orbit, and such a gravitation, with its origin in the sun, served the purpose of controlling the planetary motions. Moreover, in this same gravitation did the tides find their origin through an attraction of the moon. In this same gravitation from the sun, combined with the flattened shape of the earth, did that mysterious conical motion of the earth's axis concerned with the procession of the equinoxes find its origin, and in the laws of Galileo was to be found an explanation of the actual flattening of the earth's shape as a result of the centrifugal force of its rotation. These and many other things did Newton demonstrate in the "Principia," and by their means brought astronomy from a state of pure charlatanism to the state of order symbolized by Pope's famous words: "Nature and Nature's laws lay hid in night. God said, 'Let Newton be,' and all was light."

Even as our greatest architects strive for beauty couched in a fundamental simplicity of design, so the Grand Architect of the universe revealed himself in Newton's great work as the father of the principle of dignity of structure through ultimate simplicity. It is a great faith in the possibility of seeing in the operations of nature the working of principles which are ultimately simple which, as each new discovery is revealed, has encouraged man to hope that he may some day understand them. While today nature has revealed many treasures unknown to Newton, there are few who, realizing the great stride made in the "Principia," will not today join with Halley in his eulogy of that great work: "So near the gods man cannot nearer go."

When an outstanding genius causes science to take a leap forward beyond the vision of his contemporaries, there usually follows a period of depression in which it seems that all that is

worth doing has been done, and that what the universe has not already revealed must forever defy the power of man to fathom. Such a period followed Newton. Of course, much valuable work was done in the years which came after, but it took more the form of a development of the consequences of Newton's labors than of the discovery of new paths of knowledge. And then only about a century ago, a new page in the architectural designs of the universe was turned, and the heading on that page was *electricity*.

The forerunners in the march of science do not often come heralded by much ceremony suggestive of the power that lies behind them. Often in apparent trivialities do they reveal themselves—trivialities so void of spectacular content that but few can be found who deem it worth while to listen to their story. A hundred and fifty years ago little more was known of the science of electricity than the fact that if a black rod is rubbed with the skin of a cat it will acquire the power to pick up small pieces of paper, and, if viewed in the dark, will be found to emit a blue glow. One can hardly imagine a set of phenomena more vulnerable to the scoffer; for black rods and cats have been the stock paraphernalia of witches from time immemorial—the blue light visible in the dark adds no particular prestige to the phenomena. And then, we find that these things will not reveal themselves in the presence of water. Now, we should say that water destroys the electrical insulation, but the scoffer who had heard so much of the fundamentality of that triumvirate, "earth, fire and water," might find ample wherewithal to whet his sarcasm, and even though he should admit the reality of the phenomena themselves, he might well attack them on the basis of their futility, for it would appear that if all the black rods in the world were rubbed with the skins of all the cats, the most that might hope to be accomplished would seem to be the raising of a small weight of totally insignificant amount. And yet, on this earth at that very time there existed, and within the reach of man, the wherewithal to make a dynamo. To one who contemplates the enormous manifestations of electrical power today, it seems almost inconceivable that all of these potentialities could have remained dormant for the whole period of man's civilization.

The Royal Institution of Great Britain was founded by Count

Rumford in 1799. Its stated purpose is "the promotion, diffusion, and extension of Science, and of useful knowledge." To its lectures, given by Sir Humphrey Davy at the beginning of the last century, came a young bookbinder's apprentice, whose enthusiasm sufficiently impressed the lecturer to result in his being appointed as assistant at the Institution. Unfortunately, it became necessary for the young man to have some money wherewith to live, but there was no money for scientific assistants. However, the Institution had an appropriation for janitors, and so the bookbinder's apprentice, Michael Faraday, became janitor at the Royal Institution. I do not know how efficiently he performed his duties in the office of janitor, but even though he may have neglected the windows of the laboratory, he cleaned well the windows of science, and even though he may have neglected the cobwebs on the walls of the building, he cleaned many of them from the horizon of knowledge.

The fact that wires carrying currents possessed in many respects the characteristics of magnets was already known, but it fell to Faraday to discover the fact that batteries were not the only means by which electric current could be produced, and to demonstrate the fundamental principles upon which electrical engineering is based today. By the labors of that little group of men, Ampère in France, Faraday in England, and Henry in this country, we came into possession of most of the facts governing the broader features of electrical science, of the facts which tell us how to build a dynamo, a motor, and the like. We came to know of strange new forces with mysterious relations between them. But what was their explanation—what was the secret of their mutual relations—of what broad principles of the design of the universe did they form a part? Then came Clerk-Maxwell, who sought to correlate these discoveries into a more harmonious unity. Maxwell was a great mathematician; and, as a result of his labors, he wrote a book which few could read, but which, in the years that have followed, has served to mould our thoughts to that comprehension of the subject which we enjoy today.

The place of the mathematician, of the dreamer, in natural philosophy, is not always apparent to the layman. He takes the facts which the experimenter gives him, and seeks to correlate them as part of a greater framework of truth, in the hope that

the frame itself shall suggest other things which may be true, and thus stimulate further search and widen our comprehension of the whole. A man coming to us from another country, or from another world, might, by observing the actions of our President, our Secretary of Labor, and the governor of one of our states, form some sort of an opinion as to the probable actions of these individuals under given circumstances. His understanding of the whole situation would, however, be much less complete than it would be were he acquainted with the whole mechanism of our constitution, or even with some part of it which was fairly complete in itself. If his knowledge is confined within the limits we have supposed, however, he might take such information as he had and try to reduce it to some sort of order by building in his mind a constitution of which such individuals as he knew formed a part. In this creation of his mind, he would have to picture many new individuals and offices in order to complete the framework of his thought. He would naturally suggest a search for these individuals. Every additional one found would add more certainly to his general plan, while every one he failed to find would give him a clue as to how his plan should be modified in order to conform to the facts. When all was complete, or, indeed, long before all was complete, long before he knew the status of every minor clerk in the government employ, he would be conscious of a much better understanding of the whole situation, and would be in a much better position to draw upon the services of the government than he was when the whole of his knowledge was confined to the actions of the three individuals we named at the start. If this man, who corresponds to our mathematical physicist, should now go back to his own people, he would doubtless have much difficulty in making them understand the plan of our government. The facts they would have to accept, but it might be only after prolonged experience of our actions that the mechanism of our procedure would enter into their inner consciousness with that force which implies understanding.

So, Maxwell sought and found a beautiful scheme of thought in which to comprehend and harmonize the discoveries of his predecessors. The form of his scheme was such as to suggest that it should be possible to propagate electromagnetic disturbances in the form of waves in an all-pervading medium, and

that certain of these waves should have the properties of light waves, and that all should travel with a velocity equal to that of light. His conclusions in the latter respects were beautifully verified by his calculation of the correct velocity of light from purely electrical data, and his predictions in the former have received wonderful justification, first in the experimental work of Hertz and Lodge, and finally in the modern development of wireless telegraphy and telephony in the hands of Marconi and others, developments which at every stage of their progress have drawn upon the principles outlined in Maxwell's great work. We now know that the electromagnetic waves of wireless, heat rays, light rays, the ultra-violet rays used therapeutically, X-rays, the gamma rays emitted by radium, and the cosmic rays of which we have heard so much recently, are all special cases of electromagnetic waves, differing from each other in their essentials only as regards their length. The longest are the wireless waves, which attain lengths of the order of a mile, and the shortest constitute the cosmic rays, whose length is comparable with the one-millionth of the one-millionth of a centimetre.

And then, following Maxwell, once again science made one of those pauses for breath in which many seem to see the end of all that man may hope to know,—those dread pauses in which the horizon of discovery seems the boundary thereof.

Thirty years ago was a time of great depression in physics,—a time when would-be Ph.D.'s went about like roaring lions seeking something to measure and finding nothing but the density of a gas or the viscosity of a solid. The sentiment of the times was well voiced by a certain European physicist of eminence, who stated that it was probable that all the important experimental discoveries in physics had then been made and that henceforth the investigator must confine himself to a repetition of what had been already done, with greater attention to minor matters of precision.

Even in those days the apparatus cases of most laboratories contained curiously-shaped glass tubes containing rarefied gases of various kinds, which could be made to glow in fantastic manner by sending an electric discharge through them. Few sought to penetrate the mysteries of these tubes. They would be brought forth on the occasion of popular exhibits in

the laboratory, made to go through their alluring performances, and then returned to their cases to await the next festivity of the kind. They were not viewed as serious articles of scientific research, but hardly as more than toys. And yet, what a marvellous secret they held! For it was in one of those tubes that, in 1898, J. J. Thomson discovered one of the two fundamental bricks out of which the universe is built—the electron—the tireless worker whose home is in the atom—the thing whose quivers send us light from the sun, whose ceaseless flight around the atom's center gives the magnet the power to pull—the thing whose motion through the electric cable constitutes the electric current—the thing whose splash when hurled into the atom with great speed is the X-ray—the thing whose motions in the antenna send us wireless waves, and whose motions in the radio tube enable us to detect those waves. It is electrons from the sun which are responsible for the aurora. The atoms of which matter is composed are so small that about a hundred million of them laid in a line would take up but the length of one-third of an inch, but the electron is so small that even in comparison with the atom it is but as a fly compared with a cathedral. It is so light that if everything were magnified in mass so that the electron attained a mass of four ounces, that four ounces would be on the same scale of magnification become as heavy as the earth.

Before the discovery of electrons we had cause to believe that there were such things as atoms and molecules, but nobody ventured to picture their structure, and we felt we had gone far in penetrating nature's mysteries when we were able to say that, on the basis of certain plausible considerations, it was probable that if a drop of water were magnified to the size of the earth, the molecules would become as large as small shot. The discovery of the electron gave a fresh impetus to man's hope of understanding the atom, and before long the second fundamental brick of nature's structure revealed itself—the fundamental unit of positive electricity—the proton, whose natural home is in the nucleus, the heart of the atom. The proton is two thousand times as heavy as the electron, but it is two thousand times as small, so that if the proton were magnified to the size of a pinhead, that pinhead would,on the same scale

of magnification, attain a diameter equal to the diameter of the earth's orbit around the sun.

At the end of the last century Röntgen discovered X-rays. The property by which they first claimed attention was their power to pass through flesh and so show shadows of the bones of the body. Soon, however, it was realized they were endowed with many other properties of a most important and interesting kind, properties which were bound up with the atom's structure and whose studies therefore served to throw light upon that structure.

Until the end of the last century, one of the most firmly established beliefs was that of the permanence of the atoms. However, near its close, Becquerel found certain curious properties of uranium oxide which suggested that this substance was continually emitting some kind of a radiation which could pass through screens opaque to light and affect a photographic plate. Several other substances were discovered possessing this property, and many other characteristics of these substances were discovered, characteristics which could only be harmonized on the belief that the atoms of these substances were in a continual state of spontaneous disintegration—of atomic explosions, if you will, and that the phenomena observed were the symbols of these explosions.

One may naturally be led to inquire how far discoveries in pure physics and mathematics find their reflections in the things of everyday life, in the sense which we call useful. If in a great city we should set out on our travels with the intention of visiting all the places within the field of our immediate interests to the exclusion of others, and if we should refuse to walk along any street which did not itself contain many of these places, then, even as regarded those things to which our interest was confined, we should limit greatly the possibilities which that city opened to us. If this is true of a relatively simple structure like a city, how much more is it true of that beautiful framework of science whose parts are so clearly interwoven that it is almost impossible to touch one of them without producing response in all the others. While, therefore, the man of science must pursue knowledge for its own sake, it is a remarkable fact that practically all of those achievements in the physics of the past twenty years which might be classed as utilitarian, have arisen directly from, or in relation to, investigations pursued with no utilitarian motive directly in view. X-rays revealed

themselves first in the light of their importance in surgery. The study of their properties shed a new light upon the structure of the atom, and this light was reflected back with enhanced intensity to clarify the properites of the X-rays themselves. The immediate application to photographic surgery was obvious, but that field which is concerned with the effects of the rays upon body tissue, upon the cure of cancer and the like, was not so evident. Bound up as it is with the properties of the rays in relation to their passage through matter, with their absorption in the tissues, and the extent of the molecular disruption which they produce, it must draw for its development upon the more fine-grained aspects of the study of X-rays which the physicist has made in the field of his own interests.

The study of radio-activity has taught us that in the spontaneous disintegration of the atoms which accompanies this process, powerful radiations are emitted. First we have the alpha particle, a positively charged atom of helium, with a velocity of eighteen miles per second. Then we have electrons travelling with a velocity ten times as large, and finally we have a very hard type of X-ray known as gamma rays. These rays possess the power to disrupt molecules through which they pass, and it is this power which gives them, in common with X-rays, such great value in medicine. The surgeon's knife can dissect the tissues and remove the larger malformations of growth, but the X-rays, the rays from radium, and those of ultra-violet light can dissect the malformation on things ten thousand times smaller than the smallest thing which our microscope can reveal.

The detailed investigations of phenomena pertaining to the passage of electricity through gases—phenomena whose study led to the discovery of the electron, necessitated an improvement in our methods of producing high vacua. The pumps of today can accomplish in fifteen seconds what would have taken a couple of hours twenty-five years ago, and the vacua attainable are ten thousand or more times better than they were in those days. We can now reduce the pressure in our apparatus by means of modern pumps to such an extent that only one in every hundred thousand million of the molecules originally present remains. This improvement in the technique of producing high vacua, rendered necessary for investigation in pure science, has rendered possible the electric lamps which we use today. It has rendered possible the modern X-ray tube—an instrument

not only infinitely more reliable than the weak and capricious tubes of twenty years ago, but controllable in intensity to amounts twenty times as great as those formerly attainable. It is only through the aid of modern vacuum technique that the modern broadcasting station has been rendered possible, that the amplifying tube has become a reality, and that we can have wireless transmission of signals, speech and photographs.

If, twenty years ago, we had wished to give an example of a type of research which was least likely to have a utilitarian value, we could hardly have chosen a more fitting example than the investigations which Prof. O. W. Richardson had been carrying on in England, and later at Princeton, on the emissions of electrons from heated wires; yet it is to these investigations, combined with the power to produce high vacua, that we owe the modern radio tube, the X-ray tube, and a variety of appliances used in the general fields of radio transmission and X-ray technique.

It has long been known that light when falling upon the surface of certain substances possesses the power to eject electrons from them, and the study of this phenomenon has been one of primary importance in relation to our knowledge of atomic processes. But it, too, has had its practical application, for it is this phenomena which has rendered possible the wireless transmission of pictures, and a variety of other things hardly less important even though less spectacular.

Many years ago, Rowland, of Johns Hopkins University, showed us how to rule very fine closely-spaced parallel lines on speculum metal, and use them to analyze light into its component colors. That which the grating does to the light can be predicted if we know the spacing of the lines; and, conversely, if we had known beforehand the nature of the light, we could have gained information regarding the spacing of the lines. Since X-rays are of the same general nature as light, but of much shorter wave-length, it became a matter of interest to inquire how far such methods could be applied to them. It soon appeared, however, that for the successful pursuit of this problem it would be necessary to rule lines whose distance apart was of the order of one-hundred-millionth of a centimetre. We cannot, of course, make such ruling, but nature has provided us with something very like them in the regularly-spaced atoms which constitute a crystal of rock-salt, for example. About fifteen years ago, Laue found that he could make a crystal act

in relation to X-rays in very much the same way as Rowland's gratings acted toward light. The matter was pushed rapidly forward by a number of physicists, and soon gave accurate means of measuring the form of distribution and spacing of the very molecules of the crystals. It is quite impossible in a short space of time to give any idea of the tremendous field of activity which these discoveries opened up in relation to atomic structure on the one hand, and the nature of X-rays on the other. Not only this, but it soon became realized that there were other fields of usefulness for the new method. Not the least among these has been its application to the structure of metals, which has provided the metallurgical engineer with a new method of attack in the detailed examination of his alloys, and of the effect of strain and other treatment upon them. Whereas formerly the limits to the fineness of his examination were determined by what his microscope could see, he is now almost in a position to look at the very molecules themselves.

Many years ago, Professor Michaelson, of the University of Chicago, became interested in the question of whether or not the velocity of light is affected by the earth's motion. This is an experiment having, at first sight, nothing but a philosophical interest. But Professor Michelson obtained an unexpected result, a result which did not harmonize with our understanding of nature's laws; and herein lay its great value, for it showed that our modes of thought required revision. This great revision, not, of course, in the laws themselves, but in the sense in which we interpret them if they are to harmonize throughout, constitutes the theory of relativity,—a way of looking at things which soon made its influence felt outside of the domain in which it was born,—a scheme of thought which has enabled us to see harmony in, and so understand, many wonderful things in the theory of electricity, atomic structure, and other branches of physics. Moreover, here again, we meet with a remarkable example of the interdependence of the various parts of science on each other. Of all branches of pure mathematics one could hardly conceive any farther removed from nature than those having to do with non-euclidean geometry and the so-called absolute calculus of Ricci and Levi-Civita. These were fields so specialized as to be studied only to a very limited extent by mathematicians themselves. Yet, even as an archæologist might suddenly come upon a scroll of papyrus outlining the laws of an ancient civilization, and might therein find the

means to harmonize and understand the other visual records which his search had unearthed so Einstein found in these abstruse writings of the mathematicians the wherewithal to express the unity of nature's laws in a form so beautiful that he has likened that expression to a wonderful symphony of which our universe is the expression of God's rendering.

Astronomy, the most ancient of the sciences, has always occupied a place in the forefront of the imaginations of the scientist and the layman alike. With the motions of the planets co-ordinated by Kepler, and moulded into a beautiful scheme of physical law by Newton three hundred years ago, there seemed but little more that man could expect to discover. The growth of the science of optics soon provided a tool wherewith to explore farther, however. Laboratory studies of the nature of the light emitted by incandescent solids and gases soon provided a means of determining much concerning the heavenly bodies by a study of the light which they emit. Stars which are so far away that their light, travelling towards us at the rate of 186,000 miles per second, takes thousands of years to reach us, may move with great velocity without that velocity making itself apparent by direct observation. A study of their light has enabled us to determine their speed in very much the same way that we could determine the speed of a train by noting how much the pitch of its whistle is altered by the motion.

The stars are so far away that even in our most powerful telescopes they appear but as points in spite of their great size; but by drawing in greater detail upon our knowledge of the way in which light comes to us and of the effect of the size of the emitting body on the character of the light, Professor Michelson, at an age when most men are content to rest upon their laurels, performed one of the most brilliant feats of a lifetime of masterly achievements, in measuring the diameter of one of these stars, a feat equivalent to measuring the diameter of a penny at a distance of a thousand miles.

Strange as it may seem that we can learn so much about the stars which are so far away, the last few years has enhanced still further the wonder of it all. For the knowledge which we have gained about matter by experiment in the laboratory has found a most remarkable field of application in enabling us to understand the conditions which must prevail in the stars; and, these stars by their peculiar characteristics of large size,

high temperature, high density, and so forth, have provided us with conditions to test our conclusions such as we could never have hoped to attain in the laboratory. A gas compressed to a density eight thousand times that of steel is but a figment of the imagination in the laboratory, yet of such stuff is the Companion of Sirius made. The temperatures of forty million degrees correspond to things ten thousand times as hot as any temperatures we find on earth, yet nature has realized such temperatures in some of the stars. And so the stars, far from being things through which we dare hope to learn but little, have, by their exceptional condition, served to provide us not only with a very fascinating story of their own life history, but with a large part of the story of the birth of matter itself.

Discoveries in the fields of experimental science naturally go hand in hand with that study of the laws of design of the universe which we call theoretical science. One supplements the other, and the strength of one enhances the strength of the other. It is naturally around the atom's structure that the thoughts of man have loved to hover. And here, the power to comprehend a new point of view has grown enormously in the last few years. We have a clearer understanding of what understanding means. We were in danger of becoming so enamoured of those laws which govern the behavior of matter in bulk as to refuse to admit any other possibilities in respect to the laws of the atom. The workings of the coarse-grained things of nature were all about us. Pulleys, springs, water torrents, the waves of the sea, these were things of common experience, and the mind sought contentment in the thought that the atom might utilize in its structure only things which behaved as these things behaved; and even as a little hill may hide the Alps from one whose life is in its shadow, so there was danger in the known and obvious workings of the common things around us obscuring from our vision the story of that great universe of the atom which lies beyond. Happily, the complacency of our outlook has received, in recent years, one or two serious jolts. First came the theory of relativity, which taught us that a greater elasticity of thought was necessary if we were to understand nature as she is rather than as we might have made her. Then came a series of experimental phenomena which seemed to violate all our notions of how things should be, and since we could not alter the experimental phenomena, we had

to alter the notions, and as there arose the so-called quantum theory of atomic structure,—one of the most helpful crystallizations of thought for correlating the facts that we have ever had. And then, as further search showed this theory to be inadequate beyond a certain stage, there arose only a couple of years ago, an entirely new way of regarding the atom,—a way so radical in its point of view that it is safe to say that had it been put forward fifteen years ago it would hardly have attained a hearing. Born in a day of more liberal thought, however, it had no sooner made an appearance than a host of workers arose to welcome it and to develop its consequences, so that today there is hardly a physical laboratory in the country which does not contain one or more people who have acquired the power to think in its terms.

In thinking of theories being discarded and superseded by others, we must not think of the discarded ones as useless. The situation is not so much one where we are to think of a certain theory as right and all the others wrong. In a sense, different theories are like different languages for describing the same phenomena. The English language may be more suitable, more powerful for the purposes of the science of chemistry than the French language. It may have a greater richness of word content; but to say that one is right and the other wrong, is utter nonsense.

And so, a quarter of a century after the prediction of the eminent European philosopher to the effect that discovery was ended, we find ourselves in the most intensive period of scientific activity of all time. We may well ask where we are headed. Shall we continue to discover new treasures, or, when we have catalogued those we have, shall we reach again one of those periods of stagnation? If we do, and if there be anyone who then feels that progress is ended, that knowledge is complete, and that science is dead,—let him think of how confidently he could have voiced that same thought in the civilization of the Pharoahs. Let him think with what surety he would have voiced it in the years which followed Newton. Let him think how he would have voiced it—yes, perhaps how he did voice it—thirty years ago, and then let him take hope. For the words of the Bard of Avon are truthful yet. There is more in heaven and earth than is dreamed of in even twentieth century philosophy, and the richness of nature's content will not be fathomed in our time.

Elementary Science in English and American Schools

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Science occupies a relatively minor part in the elementary school curriculums of England and the United States. Bray states that time allotted to nature study is eighty minutes per week out of a total weekly time distribution of sixteen hundred and fifty minutes.[1] Sadler's statistics on time allotment in English schools is in very close agreement with Bray's figure.[2] However, this time allotment is higher than it is in the subjects of history, singing and geography. At the present time, the amount of time spent in Nature Study in the elementary schools of the United States is probably no higher, if as high. Specified text books are not used in either country. In both countries the exact nomenclature used in reference to the science course varies somewhat. Until comparatively recently the commonly used term in the United States has been "Nature Study." England has followed, in general, the same nomenclature, but such titles as "Object-lessons," "Observation-lessons," "Lessons of Common Things," and "Elementary Science" have been used. This variety in names is quite characteristic of the English school systems, which are probably more varied in regard to courses of study and methods than any other school system in the world.

The purposes of science in the elementary schools of England have been clearly set forth in the "Board of Education Suggestions to Teachers" and in the 1918 report of the committee appointed to inquire into the position of science in the educational system of Great Britain. The "Suggestions" state that the purpose is "to deepen the interest of the child in the world around him by some elementary study of the simpler phenomena of animate and inanimate nature and to train him in habits of careful *observation* and clear thinking, which will in turn give certain mental habits useful in the later study of the sciences. Accuracy and thoroughness are as essential in Nature Study as in any other subject and to make clear

1 Bray. "School Reorganization."

2 Sadler, M. E. "Our Public Elementary Schools."

the child's first confused impressions, *drawing* and *modelling* are almost essentials. Children's observations should have a bearing on one another and should lead up to something definite."

Quoting the committee report as to the value of science and its place in education: "It can arouse and satisfy the element of wonder in our nature. As an intellectual exercise it disciplines our powers of mind. Its utility and applicability are obvious. It quickens and cultivates directly the faculty of observation. It teaches the learner to reason from facts which come under his own observation. By it the power of rapid and accurate generalization is strengthened. Without it, there is a real danger of the mental habit of method and arrangement never being acquired. Those who have much to do with the teaching of the young know that their worst foe is indolence, often not willful, but due to the fact that curiosity has never been stimulated and the thinking powers never awakened. Memory has generally been cultivated, sometimes imagination, but those whose faculties can best be reached through external and sensible objects have been left dull or made dull by being expected to remember and appreciate without being allowed to see and criticize. In the science lesson, the eye and the judgment are always being called upon for an effort, and because the result is within the vision and the appreciation of the learner, he is encouraged as he seldom can be when he is dealing with literature. It has often been noticed that boys when they begin to learn science receive an intellectual refreshment which makes a difference even to their literary work." The above quotations give an insight into the theory underlying the purposes of English education and consequently formulated into practices.

The purpose of elementary science, briefly stated, is to give information that will be of value when the individual becomes an adult. No other subject in the school curriculum is so wide and unlimited in its scope as nature study. First hand, intelligent and accurate observation is stressed. "The scholars should be taught to observe, contrast, compare, and in general acquire a knowledge of common things, and describe accurately what they see."

The Handbook of Suggestions (1927) issued by the Board of Education discusses the aims, content and methods in nature

study in some detail. The following is a summary of the aims and description of the courses in the three stages as stated in the handbook.

The main purposes in the study of Nature are: (1) The awakening of interest in plant and animal life and in natural scenery; (2) The simple investigation of common phenomena and the broad scientific principles underlying them. The Board of Education also expresses the belief that the science lesson should give opportunity to satisfy the children's natural inclinations in handling apparatus and in observation of the way things work, and that books cannot take the place of observation and experiment, but are useful when interest has been aroused.

A brief summary of various school stages follows.

THE INFANT STAGE (5-7 YEARS OF AGE)

Nature study should attempt at this stage to merely keep alive the children's interest and curiosity in science, leading them to make observations which can be put to fuller use later. Keeping and feeding of animals, growing and care of plants in the schoolroom, noticing effect of pouring water into various kinds of soil, floating objects on water and making of nature and weather calendars, are a few suggested activities. Stories from appropriate books are better than formal instruction during the winter season.

THE JUNIOR STAGE (7-11 YEARS OF AGE)

The children in this stage should have constant opportunity for close contact with plant and animal life, for observing the main features of the district around school, and for noting the simpler natural phenomena. Work at this stage should further the aims of the Infant Stage and at the same time be more exact. The children are supposed to assume more responsibility for looking after plants and animals kept indoors. Simple aquaria stocked with suitable pond life are suggested for each school room. Visits to parks, gardens and fields for purposes of observing plant and animal life should be made. Pupils in this stage are supposed to keep notebook and drawing records of their observations. Practice in interpreting structure by means of pencil or brush, followed by a short description in writing, is considered essential. Modeling and construction

should be encouraged. In towns, lessons on inanimate nature should receive more stress. Simple lessons on such subjects as the formation and color of soap bubbles, the different kinds of images in mirrors, the effect of prisms on light, and the action of the magnet and simple electrical phenomena appeal to the children's interest. The chief mistake made by teachers at this stage is to attempt to deal with abstract generalizations of science in set lessons on such subjects as "the properties of matter," "solids, liquids and gases," "the work of the leaf, root and stem." At no stage—and least of all in this stage, should generalizations be attempted unless they are founded on and justified by the children's own observations and experiences.

THE SENIOR STAGE (11 YEARS AND UPWARD)

The chief danger at this stage is an attempt to cover too much ground and to undertake work that is too advanced for children of this age. The following types of work are suggested: (1) simple study of the physics and chemistry of air and water; (2) simple experimental lessons on mechanics and physics; (3) elementary study of the conditions necessary for the healthy growth of plants and animals. Experimental work needs to be stressed at this stage. The making and repairing of apparatus at school and at home, the investigation of common appliances, and the solution of practical problems are suggested as suitable for the Senior Stage. In this stage, work need not be uniform for every child, but varied according to needs of the individual, if possible. Investigations and field work should have a definite aim. Insects may be used as studies in life history. Surveys of the district, experiments on soils, study of bird life, and the making of collections are given as examples of activities that are desirable. Correlation of science work with other subjects is suggested as desirable.

The method of instruction is almost entirely observational and oral with a recent tendency to stress experimentation in the Senior Stage. The teacher may do some guidance, but on the whole the class is expected to ask the questions, do much of the experimenting and demonstrating and talk about the subject, rather than have the teacher talk about the subject. Local environment is always taken as a starting point in nature study. Excursions and school gardens are emphasized, especially the former. Home-made and school-made apparatus are

advocated by school authorities. In the upper grades differentiated courses for boys and girls are given, with emphasis on the practical aspects. There is an absence of technical terms and very little written work is required. If written work is required, it is usually of the note-book type and very often is based on the individual's own observations.

A typical nature study syllabus of a city infant school English is as follows:

The plant, its parts and their functions; stems; pressing and mounting flowers and leaves; young flowers and their foldings; folding of developed leaves; collection of seeds, roots, fruits and nuts.

Stems, their use to plants, their kinds. Roots in same way.

Flowers: To recognize buttercups, dandelions, daisies, cowslip, primrose, rose, waterlily, wallflower, forget-me-not, garden pea, snowdrop, etc. To recognize catkins of poplar, hazel and oak; to examine, draw and mount specimens.

Leaves, their uses, forms and arrangements; buds; modes of protection.

Fruits, their seeds; examine various seeds; sow seeds and note process of growth; drawings.

Trees: oak, elm, beech, hawthorn, lilac, poplar, horse-chestnut, elder, etc.

How plants defend themselves.

Grasses: Collecting and mounting.

Animal life: History of frog, butterfly, dragonfly, worm; a pond and its inhabitants; bees, squirrels, spiders, fly. Structure of birds and adaptation to life; sparrow, song birds, water birds.

Our minerals: Coal, iron, tin, salt, chalk; how obtained and used. Wind, rain, snow, frost and mist.

The above syllabus emphasizes observation and classification. The aim is to give some knowledge of the different parts of plants, trees, and flowers; of their growth and adaptations to environment. Animals are studied in a similar way.

The English courses in Nature Study are very similar to those found in the United States in the past, and which still exist in many localities. However, recently in the United States there has been developing a feeling that the term "Nature Study" has been greatly abused and that the term "Elementary Science" more nearly expresses our ideals and purposes in having a course of introductory science in the grades. This term rather conveys the idea of continuity—a carrying-over of the science course through the grades into the Junior High School. Nature Study in the United States has been organized on the basis of a psychological view which is no longer held—the serial theory of child development—that certain abrupt changes occur at various times (beginning of Junior High School age, etc.,) with the result that Nature

Study has been such as to emphasize *observations* and *myths.* (The latter gained from reading stories, poems, rhymes, etc.) In fact much of the nature study has been reading poetry about nature, which, while not entirely to be condemned, has often been more poetry than nature study. The above theory held that children were too immature to do any reasoning or thinking, so observation and "love of nature" have been stressed. As a result we have had observation but sometimes very little else. In a majority of cases it has been meaningless to the child and very often to the teacher. The result of these criticisms has been an attempt to develop a course of study in elementary science which will be of functional value to the child —a course of study that will be "meaningful" to the child and have observation that is purposeful rather than haphazard. We have hoped that the observations stressed were worthwhile or would lead to something worthwhile—that they were fundamental, but we have stopped there, without answering the more important question of "fundamental for what." The new idea is that beginning science must have a meaning in the grade level in which it is taught. This new viewpoint is used as a point of departure in the Elementary Science Course of Study of the Horace Mann School of Teachers College. Too often it is felt that purposeless, meaningless observation has led the pupils to hate nature study rather than love it, thus defeating the very ends which the Nature Study course set out to do.

In both countries the courses of study are very flexible as to requirements, leaving it largely up to the teacher as to actually what is taught. Physical sciences, especially in the upper grades, receives more attention, in comparison, in English schools. For this reason Elementary Science reference books more nearly resemble our secondary books both as to content and general make-up. Text books are not used or advocated in either country, but there are several good reference books for use of the teacher. There seems to be a scarcity of reference books for pupils in England as well as in the United States.

Scales for Rating Pupils' Answers to Nine Types of Thought Questions in General Science

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TYPE V.—DISCUSSION

Discuss the development of the Pure Food Laws.

Value 0

Pupil Answer. The development of pure food law is very good because, people is suppose to eat pure food and not to eat unwholesome foods. Because it is injurious to health.

Criticism. Practically no knowledge of the laws is shown, the discussion giving rambling and poorly constructed statements of why pure food laws are necessary.

Value 1

Pupil Answer. Before the pure food laws were made the grocers and butchers would used different preservatives some of which were poisons.

Criticism. Some vague knowledge of the question is shown, in that the answer mentions the use of poisoning preservatives by merchants. It does not tell of the different foods affected by the law, nor does it discuss the laws themselves.

Value 2

Pupil Answer. The development of the pure food law has been very great during the last few years. This law has effected milk, meat, eggs, breakfast foods, cheese and in time it will effect all the things that are sold. For example the farmers cannot sell their milk unless all cows are T.B. tested.

Criticism. This paper mentions that the law covers the sale of milk, meat, eggs, and so forth. The adulteration of milk and cereals is not mentioned nor is the provision for correct labeling stated. The first sentence is valueless in the discussion. The last sentence contains a false statement, as testing for tuberculosis is controlled by counties and states, except in the meat packing industry.

VALUE 3

Pupil Answer. Not so very long ago people used to mix water with milk, sawdust with cereals etc. therefore the food was not what it was supposed to be. In 1917 a law was passed stating that all packages, bottles etc. should be labeled telling exactly what was in them and the net weight.

Criticism. Clear illustrations of adulterations in milk and cereal are presented. This paper also tells that provisions calling for correct labeling, formula, and net weight are required. A reader is led to imply that the first Pure Food Law was passed in 1917; the date of 1906 is entirely omitted.

VALUE 4

Pupil Answer. During the war some factories added materials to their products so there would be more of them and they would keep longer. Milk for instance was one. They added water to make more and products which would enable it to keep sweet longer. In June 1906 the first "Pure Food Law" was made, and in June 1917 the last one was past.

Criticism. The date of the first Pure Food Law (1906) and the last amendment (1917) are given. This answer says that milk was adulterated and preservatives used, but fails to apply these points to other foods. It does not mention correct labels and weights. This paper gives the false impression that the conduct of the factories during the war brought about the Pure Food Laws.

VALUE 5

Pupil Answer. Meats must be stamped before they are stored. Compostions on canned food and must be told on the can. Weights must be said. Milk must be tested, no alderations allowed. Every process of canning or pickling foods must be extremely sanitary alderations should be told if there are any in foods. No preserves are allowed in any food. These are all pure food laws, and there is a penalty for the manufacturer or retailer who violates them. These laws are not very old being made only a few years ago. People before then could do what they pleased with food. These laws protect the people's health.

Criticism. The matters of "stamps" on meats, correct labels and weights, and the rulings against preservatives are clearly presented. This is a better general discussion than Number 4, which speaks principally of milk. The date of passing of the Pure Food Laws, the effect of the laws in stopping graft, and a discussion of adulteration, are points that are omitted.

Value 6

Pupil Answer. In the year of about 1906 the people complained of some of the food that was on the market especially meat was bad so they appealed to the Senate who made a law called the pure food laws that was finally passed. The food such as meat and canned goods were tested by the government to see if they were pure and if so they put their stamp on them. this stamp was an insurance that the food was pure. At the present day the majority of canned goods and meats are inspected and there is little danger of it being spoiled, or mixed with cheaper material. This law was especially to keep grafters from mixing material in with other foods and selling it at a high price. The Pure food law was proposed in 1906 and went into effect in 1907.

Criticism. The topic of adulteration of food is fairly well handled in this answer. It mentions that the Law prevents grafters from mixing low quality food with high quality food and selling it under the latter grade. The date of the passage of the Pure Food Laws is given. Milk inspection is not mentioned nor is the point developed as to the lack of sanitation in the handling and sale of foodstuffs before the passing of these laws.

Value 7

Pupil Answer. In olden times and even now in some European countories the people used to have stands out in the streets where they would sell their foods. The flys and other insects would get on the food and it wouldn't be a bit sanitary. Now days in America the have pure food laws which govern the selling of foods in the streets and open stands. These laws also make the dairyman test their cows for T.B., and it also says that the meats should be kept in refrigerators or ice cold rooms.

These pure food laws are inforced by the health officer.

The purpose of the law is to prohibit the alderations of foods and have pure foods.

The law was passed by Congress in 1906, but came into use January 1, 1907.

Criticism. This paper clearly gives the facts about lack of sanitation in the handling and sale of foodstuffs before the Pure Food Laws were passed. Milk testing is mentioned, but adulteration is not clearly discussed. No mention is made of the fact that the states in many cases followed the lead of the government and passed pure food laws.

VALUE 8

Pupil Answer. Foods are adulterated either by taking out something useful or putting in something that would do us no good. This adultering was stopped by the pure food law pass by Congress June 30, 1906. Other law were passed up untill June 15, 1917, when the last one was made. Food standards were fixed on meat, all canned good fruit and vegetable alike, grain, flour, meal, and extracts. If any thing has been added or taken out the law states that it must tell on the package.

The law as first passed applied only to interstate commerce, but the states later passed laws of the same sort.

Criticism. Later amendments to the Pure Food Laws are mentioned and adulteration is clearly discussed. It is also shown that the passing of the national Pure Food Laws, which applied only to interstate commerce, was followed by many state laws. This paper deals principally with the major issue, while Number 7 treats mainly of sanitary handling of food stuffs. The reasons pure food laws were necessary, dates of amendments, and the fact the United States, by establishing pure food laws, was an example to the other countries, are facts that are not covered.

VALUE 9

Pupil Answer. The pure food laws were passed because of the adulteration of foods. It came as a result of manufacturers canners, and meat packers adulterating the products sold, so as to make an enormous profit.

This law was passed by Congress in 1906, and went into effect in 1907. It covers all products used as food, or that are used

in the preparation of food, and also drugs and patent medicines. The United States was the first to pass such a law, which has since been copied by other countries. Though the first law applied only to interstate commerce, the states soon passed similar laws.

The Food and Drugs Act was amended in 1912 and 1913.

Criticism. The need for pure food laws is developed. The fact that the United States was the first country to have such laws and became an example for other countries is brought out. The years 1912 and 1913 are given as dates of amendments. This paper fails to cite that previous to1906 all pure food laws were entirely in the hands of the separate states and cities. No mention is made of the Meat Inspection Act, nor is a summary of the present status of the laws given.

VALUE 10

Pupil Answer. Until about twenty years ago, laws protecting the citizens against inferior food were left to the separate states. A number of states had enacted such laws. Many cities, too, had legislation regarding milk, etc. But efforts to enact a Federal law had been unsuccessful.

Then in 1906, Congress finally passed the "Food and Drugs Act of June 30, 1906." This applied, of course, only to interstate commerce, and the states followed with similar laws. A Meat Inspection law was passed at the same time.

The Food and Drugs Act was amended in 1912 and 1913, and as it stands to day is "an act for preventing the manufacture, sale, or transportation of adulterated or misbranded or poisonous or deleterious food, drugs, medicines and liquors, and for regulating traffic therein and for other purposes."

Criticism. This is a clear discussion of the chief points of the question. It is pointed out that the federal law was intended to meet a real need which had formerly been inadequately met by individual states and cities. The Meat Inspection Act which was passed at the same time (1906) and the amendments of 1912 and 1913 are also mentioned. A good summary of the laws as they stand today is presented.

TYPE VI.—EXPLANATION

Tell how a siphon works

VALUE 0

Pupil Answer. A siphon works like a fauset more but if you put it in a glass of water and set.

Criticism. Practically no knowledge of the siphon is shown. The writer evidently is attempting to draw an analogy with a water faucet.

VALUE 1

Pupil Answer. The siphon can be made of glass and a tube

fill the glass with water and the pressure be strong the water is in the short piece of tube.

Criticism. Very little knowledge of the question is shown. The pupil mentions in a rambling way a glass of water, pressure, and a tube. A crude sketch is given. The statements are indefinite and it is difficult to determine what is meant by them. Pressure is mentioned, but it is not shown what connection it has with the question; neither is the use of the glass and tube explained.

VALUE 2

Pupil Answer. When the air inside the siphon is drawn out the air pressure outside is heavier than the air pressure in the siphon and the water is forced up the tube.

Criticism. A good description is given of what goes on when a siphon is started and the relation of the outside air pressure to the inside air pressure is explained. Number 2 fails to tell that the end to which the suction is applied should be lower than the end in the water. This paper speaks only of the tube and not the entire siphon outfit, which includes receptacles for holding the liquid.

VALUE 3

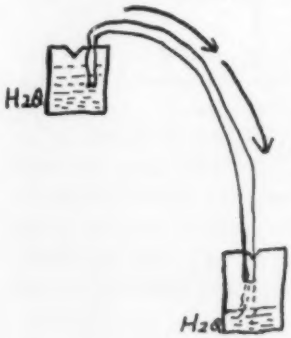
Pupil Answer. A siphon is works when you put one end in a glass of water and put the outhe end in your mouth a suct on it the end you have got in your mouth should be lower than the end that is in the glass the water in the glass has a

shorter way to go and it is going down most of the time that what makes a siphon work.

Criticism. This answer says that suction is used to start the process of siphoning and that the end of the arm to which suction is applied should be lower than the other end. Mention is made of glasses or receptacles as a part of the siphon outfit. No drawing is presented to illustrate the working process. The statements are not clear and tend to give a false impression that a siphon works by suction and gravity alone, atmospheric pressure being entirely neglected.

VALUE 4

Pupil Answer. A siphon works in following manner; the water or liquid in use must be at a higher station than that into which it is to be transferred. The siphon or tube must be filled with water to start or else be started by suction. After once starting through the tube no air can enter it and therefore the force of the air upon the water in the original basin has no opposition and because of this the water is naturally kept flowing through the tube.



Criticism. Number 4 contains a drawing of a siphon and states the principle on which it works, while Number 3 explains only how the process may be started by suction. Although it is shown in the drawing, no mention is made in the explanation that one end or arm of the tube is longer than the other, nor is it explained that air pressure causes the siphon to work.

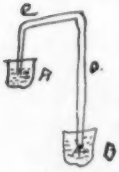
VALUE 5

Pupil Answer. A siphon is a glass tube which empties liquid from one vessel to another. One end of the tube is longer than the other. The upward force on the short arm is greater than the force on the long arm. Therefore the water is forces up in the short arm and forces down in the long arm.

Criticism. The definition and function of a siphon are given. This answer explains that one arm of the tube is longer than the other. It is intimated that air pressure causes the siphon to work. A siphon is not necessarily a glass tube as mentioned here. The description is less clear than Number 6 because no sketch is used. No definite mention is made of the part played by air pressure in the working of a siphon.

VALUE 6

Pupil Answer. The tubing is filled with H_2O so as to make the atmospheric pressure on the inside less than that on the outside.

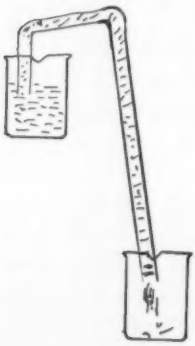


One end of the tube is placed in A. The other end in B. The atmospheric pressure raises the liquid to C from there it flows on through C and D into B.

Criticism. This paper gives a better explanation of the siphon and how it works by making use of a lettered drawing. The siphon is spoken of as tubing and not merely glass tubing as is Number 5. Air pressure is mentioned as the cause of the liquid raising in the tube. It is not made clear that the long arm must be lower than the short arm; this is shown in the diagram, but is not explained. No mention is made of the fact that a siphon, if working properly, will entirely empty the upper vessel. The meaning of the first sentence is not clear.

VALUE 7

Pupil Answer. Take 2 glass beaker and a bent glass tubing. and put water in one beaker and set one of the beakers lower than the one with water in it the fill the glass tubing with water and place each end in a beaker as shown in diagram:



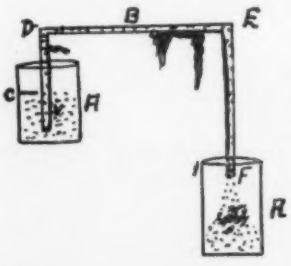
The atmospheric pressure makes this siphon work when the water was started being transferred from the top beaker to the lower it was kept running till the top beaker became empty this took place because of atmospheric pressure.

Criticism. It is explained in this an-

swer that the vessel to be filled must be lower than the vessel containing the water and that when the siphon is started and is working properly, it will continue to work until the upper vessel is empty. The failure to letter the parts of the siphon in the drawing, and then to make use of the lettering in the description, makes this answer less clear than Number 8.

VALUE 8

Pupil Answer. Water may be passed from one vessel to another by means of a syphon. Two vessels (R) are used, one at lower level than the other. The tube (b) is filled with water and inserted in each glass. In the glass at higher level it is put under the water level. The downward pressure exceeds the weight of the H_2O and water passes through the tube from one vessel to another. Atmospheric pressure lifts the water in the tube at C-D. The downward pressure in E.F. is more than the atmospheric pressure this it comes to the other vessel.



Criticism. The sketch helps to make the description of the working of a siphon clearer and more complete. The reading matter does not bring out that a siphon has a long arm and a short arm, nor does it tell the height to which air pressure will raise a liquid.

VALUE 9

Pupil Answer. A siphon is a device for moving liquids from one vessel to another, and popular for its speed and economy. It usually consists of a tube or tubing, bent in such a shape that there is a short arm, a bridge, and a long arm, like this. The short arm is placed in the container from which the liquid is to be transferred, and the long arm is put into the other container, and the siphon started by filling it with the liquid.

A siphon will operate only in case of unequal pressure, and so can be used only in moving liquids from a high vessel to a

low one. Also, because it depends on atmospheric pressure, it won't lift any liquid more than thirty-three feet.

Criticism. This paper states that a siphon has a long arm and a short arm and that, since its action depends on atmospheric pressure, a liquid cannot be lifted more than 33 feet. An attempt is made to define a siphon. It is shown that a siphon will work only when there is unequal pressure. It is not stated that the liquid will flow until the upper vessel is empty or until the levels in the two vessels are the same. The definition of a siphon is not as good as the one given in Specimen 10.

VALUE 10

Pupil Answer. A siphon is a device for transferring a liquid over an elevation to a lower level. Its action depends on air pressure.

The apparatus consists essentially of an open U-tube with one arm longer than the other. The vessel from which the liquid is to be taken is on a higher level than the receiving vessel. Then the siphon (the tube) is filled with liquid and placed with the short arm in the upper vessel, and the long hanging above the receiver. Since the weight of the liquid in the long arm must be greater than that in the short, the fluid flows in that direction, and atmospheric pressure on the liquid in the upper vessel keeps the upper arm filled. It continues to flow until the upper vessel is empty, or until the levels of liquid in the two are the same.

Increasing the length of the long arm hastens the flow. The bend in the siphon cannot be more than 33 ft. above the level of the upper vessel, as atmospheric pressure will not support a greater column of water.

Criticism. This is a clear description of how a siphon works. It is explained that the liquid will continue to flow through the siphon until the upper vessel is empty or until the level of the liquid in the two vessels is the same. This answer also shows that the bend in the tube cannot be more than 33 feet above the level of the upper vessel, as atmospheric pressure will not support a greater volume of water. Number 10 gives a better definition of a siphon than Number 9.

The Chemists Faith in the Invisible

B. Clifford Hendricks, University of Nebraska.

Yes, a chemist is a scientist, and a scientist is not usually associated with such ideas as faith. Yet, I hope to show that the chemist makes most of his new discoveries by a splendid exhibition of a most practical sort of faith. Faith in the invisible, too.

Some one has said that faith is that characteristic of our thinking which will prompt us to use truth to its utmost.[1] The chemist believes in four sorts of invisible constituents of materials. Their existence and qualities are to him truths. And even though he has never seen, with his eyes, any one of these constituents, he daily stakes his reputation as a scientist upon their existence and the dependableness of their behavior.

Fresh milk has millions of small fat droplets scattered through it. We believe they are there because they come out as the milk stands. No one has ever seen them, however. The chemist has measured their size, and this size, so small that it would take over two million of them placed side by side to make an inch, helps us to understand why they have never been seen. One of these drops would have to be made twenty thousand times as large as it is to be seen by our unaided eyes.

How much faith has the chemist in these unseen particles of oil? To answer this, picture a chemist trying to get some water out of petroleum. You think that easy? Not if it is what the chemist calls emulsified water; i. e., invisible particles of water scattered through oil as the butter fat is scattered through fresh milk. Having faith in the existence of these water droplets, even though he could not see them, Dr. F. D. Cottrell said to a chemist friend, "Put a high electrostatic stress upon the oil."[2] It worked. The oil was freed of the water and "millions of barrels of unmerchantable California oil were rendered fit for refining and for fuel purposes," by such treatment. Dr. Cottrell never for an instant doubted that those water droplets were there. He had previously made invisible particles condense out of smoke by this method. He here made such particles condense from the oil.

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1 Drake, "Problems of Religion," page 185.
2 Jour. Ind. Eng. Chem., 11: 153 (1919).

Everyone has noticed that steam from the tea-kettle is not visible until it has passed some inches beyond the mouth of the spout. There must have been water particles coming from the kettle's mouth, even though he did not see them. Here, too, the chemist sees small particles, vapor, by the aid of his eyes of faith. These particles, called molecules, are almost fifty times smaller than one of the fat droplets in the milk. It would take about one hundred million of them placed side by side to make a column one inch long.

What good has come from faith in these molecules? Some years ago it was discovered that electric light bulbs which used metallic filaments became clouded after use and failed to give their best light. It was also known that the filament wasted away and presently the lamp was dead. What caused this darkening, and how remedy it? Here is where faith in molecules helped. The chemist reasoned that, just as water vaporizes when heated, so the metal of the filament turns to gas molucules, vaporizes, when heated. Just as the cold air condenses the water vapor molecules to steam particles beyond the kettle's mouth, so the cool glass of the bulb turns the metal's vapor to the solid which coats the inside of the bulb. The filament wastes away because these vaporizing molecules are leaving it.

But how prevent all this? If these molecules of the metal could be reflected or knocked back into the metal they could be kept away from the glass and the filament prevented from "wearing out." The chemist knew there were invisible molecules in our air. He knew some of these, oxygen, would burn up the filament, and that two other kinds, nitrogen and argon, "So," he reasoned, "if the filament were surrounded by either nitrogen or argon their molecules would serve to reflect the metal's molecules back into the filament." He tried it, and today we buy the nitrogen-filled Mazda lamps. Faith in invisible molecules helped the inventor to give us better light.

The chemist thinks of every molecule as built up of smaller constituents called atoms. Each water molecule is thought to contain two atoms of hydrogen and one of oxygen. Now, if the molecule of water is invisible, certainly the atoms constituting it could not be seen. Yet the chemist considers these atoms as his building units. Dr. Ehrlich who first made and

used salvarsan, or "606," the cure for syphilis, could not have worked without faith in the reality of the atoms in his molecules. The story of his work says: "The very name '606' indicates how he accomplished his purpose—using first one substance of a known molecular structure, then another, until seeing improvement ahead, he modified first this, then that part of the [atomic] structure of his molecules until finally complete success was accomplished after 605 imperfect results, exactly as the sculptor models from his coarse clay the perfect head through a long series of incomplete, imperfect stages."[3] Note, however, the chemist is not working with or thinking of coarse clay, but rather with invisible atoms. Could he achieve such triumphs if he had no faith in them? To him they are truths, realities; he uses them.

Not many years ago the atom was the least conceivable portion of a material. It was a woman, Madame Curie, who unsettled the chemist's faith in the indestructibility of the atom. She discovered a new elementary substance which has the unusual property of giving off rays continuously. Radium, she called it. A careful study of radium has led chemists to believe that its atoms spontaneously go to pieces, and part of the debris recovered after its "tear down" always consists of many small particles called electrons which are only about 1/1800 as heavy as the lightest known atom, hydrogen. Further, chemists now believe that all atoms of all kinds are aggregates of these electrons built around a center made up of what are called protons.

It is needless to say that, if atoms are invisible, electrons would be even less so. Yet scientists, including chemists, believe in them, have faith enough in them to use them, especially in their thinking. The glowing bulb upon a radio receiving set is a monument to the inventor's faith in the electron. He reasoned that the electron's electrical properties would make it respond to what is called electrical pressure or voltage. And, since all atoms contain electrons, if the electrons could be jarred out of the atom they could be driven, even through space, by electrical influences. Heat jars them loose, and once loose they are used to rectify the electrical

3 The Future of American Medicine in the Age of Chemistry, page 32.

current or help the wireless waves to get transformed into electrical effects in a B battery circuit of a radio receiving set.

It has been estimated that "it would require 5,000,000,000,000 (five trillions) electrons, placed side by side, to cover the distance of one inch."[4] Yet these "smallest things in the world" help scientists to think straight, and such thinking is, no doubt, responsible in a large measure for this electrical age in which we live. Here then is a faith in the unseen which is, if anything, practical. It is a faith followed by works. It is not a dead faith.

There are those who are reading this who expected a more direct reference to the relation of science and religion. For such, just this: if the chemist must so constantly find his guidance through faith in unseen entities, should such habits, such training, make him less able to find help in a faith in the Unseen Supreme in his religious world of thought? Whatever the answer to this question, the student who chooses chemistry as his chief interest in college does not get very far in its perusal before he realizes that one of its most important demands is a working faith in a realm beyond his senses, peopled by colloids, molecules, atoms and electrons.

4 Slosson, "Keeping Up with Science," page 310.

An Experiment in the Use of Visual Methods of Instruction[1]

HOWARD WILBUR, Sub-Master,
William E. Russell District, Boston, Massachusetts.

THE following experiment was tried in the Wendell Phillips School, Boston, as a practical means of testing the value of visual instruction.

OBJECT OF EXPERIMENT.

To prove whether or not visual instruction in geography is worth while in grade eight of the Wendell Phillips School, and to improve the teaching of geography in the light of conclusions reached.

1 Reprinted from an article in "The Journal of Educational Method," November, 1927, by permission.

MATERIALS.

Pupils: Three eighth-grade classes of boys in the Wendell Phillips School of

(1) Parallel ages.

(2) Equal rating in so far as the judgment of teachers supplemented by the results of intelligence tests[2] could make them, according to the following standards: Inferior, below 75; Below average, 75-90; Average, 90-110; Above average, 110-125; Superior, above 125.

The classes measured as follows:

	Class 1	Class 2	Class 3
Inferior	0	1	4
Below average	5	3	3
Average	14	13	13
Above average	7	6	8
Superior	2	2	1

(3) Identical training: All three classes had received identical training in seventh grade geography and parallel previous training in geography of the fourth, fifth and sixth grades.

(4) Largely Jewish parentage with equivalent social environment and background.

Teacher: The same for each class,—the writer.

Subject matter: Geography of the Pacific States; textbook, Atwood, *New Geography*, Book Two.

Visual aids: Selected clipped pictures brought by pupils and teacher, textbook pictures, post cards and photographs brought by teacher, stereographs and slides from the school collections (fourteen slides from the "Keystone 600" set), and exhibits of Pacific states products, brought largely by the pupils.

EXPERIMENT.

Class 1 taught by the fact method without the use of any visual aids outside the textbook.

Class 2 taught by the fact method supplemented by clipped pictures, photographs, post cards, and exhibits.

2 Terman Group Test of Mental Ability, Form B, given by the writer and others. Results returned by Department of Educational Investigation and Measurement, Boston.

Class 3 taught in the same way as Class 2, with the addition of stereographs and slides.

Time given to the instruction in each class was the same—five periods of forty minutes each.

Points of emphasis were the same in all three classes.

FACT TEST.

At the close of the instruction, the following short test was given each class to ascertain the degree of fact mastery obtained:

1. The rainfall on the western slopes of the mountains in Oregon and Washington is light, heavy?
2. The changes in temperature from summer to winter along the Pacific coast of the United States are little, great?
3. Large crops are raised with the help of irrigation in northern, southern, California?
4. What great river is noted for salmon fishing?
5. There are few, many, good harbors on the Pacific coast of the United States?

(Directions were given to underline the correct answer in Questions 1, 2, 3, and 5.)

APPLICATION TEST.

One week later each class was given a short test covering the application of the same facts of the former test:

1. Why is there heavy forest growth on the western slopes of the mountains in Oregon and Washington?
2. What effect has the climate along the coast of California upon the density of population there?
3. Explain how southern California is able to raise such large crops.
4. Explain the presence of canning factories in Oregon and Washington near the Columbia River.
5. Why are the cities located on Puget Sound destined to become more and more important?

Both tests were given without previous notice to the classes, so that there was no opportunity for further study, and no mention was made of the Pacific states between the fact test and the application test. All tests were corrected by the writer, and no part credit for any question allowed. Marking was purely objective with the subjective element left out.

The results obtained by the three classes are shown in the tables.

Class 2 scored higher than Class 1 in both fact and application tests. Class 3 scored higher than either Class 1 or Class 2 in both fact and application tests, although the medians of classes 2 and 3 are the same, due to the great interval between the steps.

INFERENCES.

1. The lower scores in the application tests are due to the forgetting of facts on account of the time interval.

2. When facts are learned better they are more easily carried in memory and more effectively employed.

3. The use of stereographs and slides in addition to clipped pictures, photographs, post cards, and exhibits, greatly increases the effectiveness of instruction.

SUMMARY OF RESULTS.

FACT TEST				APPLICATION TEST (1 week later)			
% Score	Class 1	Class 2	Class 3	% Score	Class 1	Class 2	Class 3
100	13	19	26	100	5	4	12
80	8	7	4	80	9	12	14
60	6	0	0	60	11	6	3
40	1	0	0	40	2	4	1
20	0	0	0	20	1	0	0
Median Score ..	80	100	100	Median Score..	70	80	80
Average per cent Score	84.3	94.6	97.3	Average per cent Score	70.7	72.3	84.6

CONCLUSION.

In the eighth grade of Wendell Phillips School, Boston, visual instruction in teaching the geography of the Pacific states is worth while, in that it not only tends to fix the facts firmly in mind, but also increases the understanding of them, so that they may be applied more readily.

The foregoing experiment only scratches the surface of testing in the visual field and merely indicates a possible way of going about scientific evaluation. The use of smaller percentages, which would be possible by increasing the number of questions, would no doubt lead to finer discriminations and the median could be more closely placed with the smaller steps.

More tests and a wider use of the tests would enable us to draw more general conclusions. However, the evidence in this experiment is so strong that the writer is firmly convinced that the visual method of instruction has great value and deserves greater emphasis in modern education.

Industrial Motion Pictures

Three important new educational motion picture films have recently been added to the collection of films possessed by the United States Bureau of Mines, Department of Commerce. "The Story of Petroleum," produced in cooperation with the American Petroleum Institute, shows the latest engineering and technical developments in this great industry. "The Story of Iron," produced with the aid of three prominent iron companies, portrays every step taken in the production of this indispensable mineral, from the mining of the ore to the final blast-furnace operations. "The Story of the Fabrication of Copper," also made in cooperation with industrial interests, supplements the Bureau's ten-reel feature film "The Story of Copper," and shows the processes by which the metal, after it leaves the smelter, is made into the shapes necessary to meet the demands of commerce.

The Bureau of Mines has probably the largest collection of educational industrial motion picture films in the world. These films show the different steps in the production, treatment, and utilization of the essential mineral materials or make plain the safe methods of mining and preparing minerals. The films are produced through the cooperation of industrial concerns, who bear the entire cost of production.

An announcement outlining the plan of distribution of its motion picture films has just been made by the Bureau. Distribution of the films is centered at the Bureau's Experiment Station at Pittsburgh, Pa. For the year 1928, the following named subdistribution centers have been designated:

U. S. Bureau of Mines Southern Experiment Station, New Federal Building, Birmingham, Alabama.
U. S. Bureau of Mines Petroleum Field Office, 506 Customhouse, San Francisco, Calif.
Bureau of Visual Instruction, Indiana University, Bloomington, Indiana.
Visual Instruction Service, Iowa State College, Ames, Iowa.

Department of Education, Division of University Extension, Commonwealth of Massachusetts, State House, Boston, Mass.
U. S. Bureau of Mines North Central Experiment Station, University of Minnesota, Minneapolis, Minn.
Extension Division, Visual Education Service, University of Missouri, Columbia, Mo.
New Jersey State Museum, Trenton, New Jersey.
American Museum of Natural History, 77th Street and Central Park West, New York City.
U. S. Bureau of Mines Petroleum Experiment Station, Bartlesville, Oklahoma.
Cooperative Extension Work in Agriculture and Home Economics, Extension Service, Brookings, South Dakota.
Visual Instruction Bureau, Extension Division, University of Texas, Austin, Texas.
U. S. Bureau of Mines Intermountain Experiment Station, University of Utah, Salt Lake City, Utah.

The films are loaned to schools, churches, colleges, civic and business organizations, miners' local unions, and other organizations interested in the public welfare. No charge is made for use of the films, but the exhibitor is asked to pay the costs of transportation. The titles of films now available for distribution are as follows:

Story of Coal.
Story of Sulphur.
Story of Ingot Iron.
Saving Coal at Home.
Story of Asbestos.
Story of Rock Drilling.
Story of Abrasives.
Story of Heavy Excavating Machinery.
Story of an Electric Meter.
Story of a Watch.
Water Power.
Transportation.
Story of a V-Type Eight-Cylinder Motor.
Story of Steel.
Story of Alloy Steel.
Story of Gasoline Motor.
When Wages Stop, or Safety First in the Petroleum Industry.
Story of a Motor Truck.
Story of Fire-clay Refractories.
Story of Gasoline.
Story of a Storage Battery.
Story of Portland Cement.
Story of Heat Treatment of Steel.
When a Man's a Miner.
Story of a Spark Plug.
Story of Our National Parks.
"Play Safe."
Story of Lead Mining and Milling.
Story of a Rotary-Drilled Oil Well.
Story of Power.
Story of Lead Smelting.
Through Oil Lands of Europe and Africa.
Story of Dynamite.
Twelve Points of Safety.
First Aid, or the Care of an Injured Miner by a Miner.
Oxygen Breathing Apparatus.
Story of Lubricating Oil.
Story of a Rock-Dusted Coal Mine.
Story of a Mexican Oil Gusher.
Story of Lubrication.
Story of an Electric Detonator.
The Explosives Engineer, Forerunner of Progress.
Story of Copper.
Story of the Fabrication of Copper.
Story of Petroleum.
Story of Iron.

A number of these films are subdivided into topics complete within themselves, as, for instance, "The Story of Copper" may be shown separately in four complete parts, mining, milling, smelting, and refining.

Borrowers are asked to write to the subdistribution center nearest to them. If the film desired can not be obtained from that organization, or if more convenient, application should be made to the Bureau of Mines Experiment Station, Pittsburgh, Pa., where copies of all films may be obtained. Descriptive lists of the films may be obtained from the Pittsburgh Station or any distributing center.

Rushing the Message

A Short Play on Communication.

MABELLE G. BROUGHTON and MILDRED E. EATON,
Seniors, State Normal School, Salem, Mass.

Characters—Scout Commissioner.
Local Director of the Girl Scouts.
Scoutmaster.
Troop Captain of the Girl Scouts.
Mr. Ralph, manager of the local telephone company.
Troop of Girl Scouts.
Troop of Boy Scouts.
Mr. West, chairman of committee of judges.

Place—Scout Headquarters of a small town.

Time—Act I. Early afternoon.
Act II. Late afternoon.

ACT I.

(The leaders of the Scout movement are gathered together in the Scout headquarters with Mr. West. They are seated at a table in the center of the stage. Directly behind them is a window at the side of which is placed a telephone. Two small tables at either side of the stage bear home-made telegraph receiving sets.)

Mr. West. I am not sure yet that I understand what this is all about.

Sc. Com. For some time, Mr. West, there has been growing a feeling of competition between the Boy and Girl Scouts. This rivalry seems strongest in the field of signaling and communication. This afternoon we hope to settle the question, at

least for a time. We have planned a relay over which a message, which we hope you will write, will be sent. At each station the message will be sent on by a different method. See, here is the way we mapped it out. (*Map is taken up and studied in silence. Enter troop of Girl Scouts, followed by Boy Scouts. All salute.*)

Sc. Mast. Our Commissioner was just explaining to Mr. West the stunt that we are going to pull off this afternoon. You understand how it is to be conducted?

Scouts. Yes, sir.

Byron. The bicycle riders will leave here promptly at five?

Sc. Com. Yes. You see, Mr. West, we have several difficulties in handling this relay. Some of our methods depend on sunlight; still others on darkness. For this reason we are starting just before dusk. (*To Scouts.*) Why don't you tell Mr. West why we start with cycling?

Barbara. One of the first ways of sending messages was to have them carried by a messenger. During the time of Alexander the Great a message was sometimes carried from one end of his empire to the other in a very few days. Runners first carried these messages, then later horses were used. Even as late as the American Revolution the colonies depended upon horses to carry their messages. Cycling is more in the field of the Scouts than those ways, so we thought that that would be a good method to start with.

John. At the first station will be the drummers. Of course, drums aren't used now to send messages. They are sort of echoes of the way the savages used to send messages and call the tribes together by beating tom-toms. The drummers have fixed up some type of signal with the drums by which they can send messages. It is rather hard, but I think that they can do it.

Mr. West. This is interesting. A regular history of the art of communication. What are some of the other ways by which you will send the message?

Myrtle. We are using another rather primitive method of communication. We are using the smoke columns. This means of signaling was used to a great extent by the American Indians. The Scouts are using in this relay the International Morse Code. As not more than four dots or dashes are neces-

sary in writing any one letter, four smoke columns will be used. Scouts will tend each fire, so you see one whole patrol will be responsible for sending the message on at this station.

Carl. From the next relay station the messages will be sent along by two of our most expert signalers. They are going to use these. (*Shakes out the signal flags.*) They are using the Semaphore code, because of the greater speed with which it may be used. Phil can send forty-eight letters a minute using this system, while at the most one cannot send many more than thirty with the Morse code.

Irene. The next two stations to send on the message depend upon darkness. The first one of these will send the message on by a searchlight. This is somewhat of a reminder of the way the Romans used reflected light on their shields to flash the signals. The second of these will be the Ardois system of lights which, using the American Morse code instead of the International Morse code, will show a red light for a dot, a white light for a dash.

Sc. Com. (*hurriedly*). Then these telegraph sets which have been made by the Scouts will "Rush the message" here. It is time you were all on your ways to your stations. The message Mr. West will write will leave here at five. Good luck and "Rush the Message."

(*Curtain*)

ACT II.

(The leaders of the Scouts are seated at the main table, at which Mr. West is just finishing writing the two messages. George is seated at one of the small tables, Sally at the other; both are busy inspecting the wiring of their instruments. Harry is standing beside the window. Byron and Barbara stand together.)

Byron. The roads are in remarkable condition, Barbara. With luck we should be able to finish our part of the relay in from ten to twelve minutes, although part of the two miles is rather hilly.

Barbara. Your section of the road is much worse than mine, so if I'm lucky I should be able to reach the first station about the same time that you do.

Byron. I hope that you will be able to do so. This should be a test of ability to handle methods of signaling rather than physical strength.

Mr. West (*finishing and sealing messages*). It is a wonder to me that these young people did not try to use skywriting in sending on their message.

Loc. Dir. Don't remind them of it. They'll be trying that next, if you do. As far as I can see they haven't forgotten any of the ways that messages have been sent from primitive times to now.

Byron. We talked them all over and found it necessary to leave out one or two of the ways. We had to leave out the International Code of Signal Flags that is used so much in marine signaling. We also omitted the mechanical two-arm semaphore.

Sc. Com. (*who has been holding watch*). It is one-half minute before five. Are you ready? (*Both Scouts spring to the table. Mr. West holds out a message to both. They wait for the signal.*) Go! (*Scouts take message, salute, and hurriedly leave. There is a moment of silence.*)

George (*his instrument clicking*). There! Bob is at his station and is sending over a test message. Everything is O. K.

Mr. West. So you young people built your own sets?

George. Yes, sir. Sally and I worked out the diagrams for the telegraph in the Science Class. Then we thought that we would see if we could build a set. Here are the diagrams. (*Takes large diagrams from the desk, one of the sending set, the other of the receiving set.*)

Mr. West. They look fine. Can you explain them?

Sally. Of course, Mr. West. Take this one of the sending set. The sending of a message depends on the making and breaking of the electric current. When the switch is open and the key is in its natural position the current is broken. Now, you see, if the key is pressed down, contact is made between these two places. This makes the circuit. The electricity flows from the battery, through the sending set, over the wires to the receiving set and after passing through the set is grounded, the earth completing the circuit. When the key is released it is carried back to its natural position by a spring.

This breaks the circuit. The length of time that the key is held down indicates if it is a dot or a dash. A quick release means a dot; a longer one a dash.

George. This is the diagram of the receiving set. The telegraph depends upon the electro-magnet. When the current passes through the receiving set, it passes through the coils of the magnet. The soft-iron cores inside become temporary magnets. They attract the armature, which is pulled down and clicks against this rod. Then the key in the sending set is released, the circuit broken, the magnets lose their power, and the armature is carried back to its original position by a spring. It clicks against this curved bar and gives a different sound than the first click. So the movement of the key is reproduced by sounds here. (*They point out the parts as they speak.*)

Tr. Capt. Sally and George are brother and sister, so you see that . . . (*Telephone rings*).

Harry (*answering call*). Scout headquarters . . . Fine work . . . No, we haven't heard anything from the Boy Scouts yet . . . Good-bye. (*To the rest.*) That was Bettey Graves. She says that the message has been received by the girls in charge of the smoke columns without any mistakes. The drummers must have done a good piece of work in beating the tom-toms. She wanted to know if the Boy Scouts had reported.

Sc. Mast. It would look as if the girls were ahead of the boys, at least at the start.

Mr. West. So it would seem, But you can't tell everything by that. Time will tell. By the way, as I was just going to ask when the telephone rang, how was it that the telephone wasn't used in this contest?

Loc. Direc. That seemed rather a complicated instrument for the Scouts to make. The telegraph set is much simpler.

Mr. West. I see. Well, when your commissioner asked me to act as one of your judges this afternoon and said that it had something to do with the art of communication, I thought that I would bring over the new demonstration outfit of the telephone. Would you like to see it?

Sc. Com. We certainly would. Mighty fine of you to bring it over. Perhaps if you show it to these young people they will

build one of their own. (*Mr. West opens the case and puts the different parts on the table. They crowd about him as he starts to explain.*)

Mr. West. You know that when a person speaks the sound is carried through the air by waves of condensation and rarefaction. Now let us see what happens when we speak into the transmitter. There is, of course, a current of electricity passing over the wires from the time we take the receiver off the hook. The sound waves hit the soft-iron diaphragm and cause it to vibrate. Right behind this diaphragm is a small box of carbon grains through which the current passes. The vibrations of the diaphragm cause variations in the compression of the carbon grains, and as a result variations are caused in the strength of the electric current.

In the receiver we find that we have two types of magnets, the electro-magnet and the permanent magnet. Now, the variations of the strength of the current cause similar variations in magnetic strength. This causes vibrations of a diaphragm like the first one we mentioned. This causes vibrations like those we first spoke of to occur in the air, or sound waves. Then we hear.

Sally. How interesting it sounds!

George. It's a regular House that Jack built.

Tr. Capt. I hope that you will tell all the Scouts about it some day.

Harry. Look! (*Flashes are seen through the window. The Scouts dash to the window.*)

Harry. See! It's from Reed's Hill. The Boy Scouts are sending their message! It will only be a few minutes now before it will be coming over your telegraph set, George. You better get ready for it. (*George hastens to his place and takes up his pen and paper, waiting.*)

Sally. Do you see any lights from the Girl Scouts?

Harry. I'm not sure. Yes—no.

Sally. Well, I'm going to be ready. (*Goes to her seat. Lights flash for a few minutes. George's receiver starts to click. George bends over it, writing. As he finishes and starts to rise, the message comes over Sally's set. George carries the message to the table, salutes, and gives it to Mr. West. Sally*

does the same in a few minutes. Judges study the results in silence, then they whisper a few minutes. Scouts wait impatiently.)

Sc. Com. Well, Mr. West, it came out about as I expected. But we have another surprise for you. (*Brings forth a radio microphone.*) I am going to broadcast the results of this contest over the amateur radio station that both Boy and Girl Scouts built and operate. (*In microphone.*) Amateur Radio Station B. G. S. of ———— Massachusetts. We are broadcasting the results of the Boy and Girl Scout Communication Relay Contest. The Boy Scouts finished first, and if the message were perfect would receive the award, but the accuracy of the message received from the Girl Scouts was of such superiority that I have the pleasure of announcing that equal honors belong to the Girl Scouts. We have judged this contest to be a tie. The message sent by the Scouts follows:

"Civilization has advanced; the art of communication has evolved until today nothing in this field can seem impossible."

(*Curtain*)

The New Books

Modern Plane Geometry—John R. Clark and Arthur S. Otis—310 pp.—$1.36—World Book Company.

This book uses the direct challenge as a means of arousing interest and leading the student to discover the truths of the different theorems for himself. An abundance of exercises is furnished to insure mastery of the principles and methods. Many problems and applications are given to show the practical value to be gained from the study of geometry. Instructional tests, with time limits and standards, are provided.

The General Theory of Thermodynamics—J. L. Trevor—104 pages—34 diagrams—$1.60—Ginn and Company.

"This little book is intended to serve as an introduction to the study of thermodynamics, and is planned for the use of students who have some acquaintance with the calculus of functions of more than one variable. Its distinct purpose is to develop the general laws of thermodynamics with logical consecutiveness and mathematical clarity, and thus to establish these laws in a manner that can be thoroughly understood."

The Upper Regions of the Earth's Atmosphere—G. M. B. Dobson—22 pages—paper cover—85 cents—Oxford University Press, American Branch.

This is the Halley lecture, delivered May 5, 1926. In it are discussed the properties of air at great heights, and such natural phenomena as the aurora and meteors.

The Practical Value of Birds—Junius Henderson—342 pages—The Macmillan Co.

This book brings into one volume a large amount of material pertaining to the relation of birds to human welfare. It is the product of an effort to analyze and digest the North American literature on the subject, and to bring together the significant data of economic ornithology. Many references are given for those who may wish more detailed information. Part I deals with the birds in their natural elements, relation to agriculture, food requirements, and carriers of disease. Part II deals with systematic order of the families and species of birds.

Sea Shore Animals of the Pacific Coast—Myrtle E. Johnson and Harry J. Snook—659 pages—700 illustrations (11 color plates)—$7.50—The Macmillan Company.

In this book we find a non-technical account of the structure and habits of the common sea-shore animals of the west coast of the United States, from Santiago to Puget Sound. Drawings and photographs help in the identification of these. Among this subject matter treated we find the following: The collecting grounds and how to collect; Classification of animals; Life in the ocean; Sponges; Hydroids; Jelly-fish; Worms; Star-fish; Sea urchins.

Textbook of Bacteriology and Its Applications—Curtis M. Hilliard—329 pages—59 illustrations—$2.80—Ginn and Company.

This is a text for a college semester, covering disinfection, food preservation, water, milk, infection and immunity, treated in a manner suitable for Household Economics Class. It gives the fundamental concepts of bacteriology and its practical applications.

Science and Animal Life—William M. Barrows—389 pages—$1.86—World Book Company.

Science of Animal Life is general animal biology. The author's primary interest is man. Some of the old morphology and description is included, but the emphasis is on genetics, animal behavior, and ecology. It is intended as a high school text for a half-year subject.

1000 and One—the blue book of non-theatrical films—128 pages—paper covers—The Educational Screen.

This helpful book contains a list of the new and the best of the old educational films in a variety of subject groups. The films are briefly discussed and the distributors listed. There are nine one-reel lessons in General Science. Many films are listed under Natural Science, Astronomy, Chemistry, Geography, Geology, Health, and Hygiene. There is also a valuable list of 150 theatrical films which have been reviewed by a national committee and pronounced suitable for children and young people.

Home Study Blue Book—J. S. Noffsinger—21 pages—paper—The National Home Study Council, Washington, D. C.

This pamphlet contains a list of correspondence or home study schools which have the approval of the National Home Study Council.

The Nature Almanac—Arthur M. Pack and C. Laurance Palmer—312 pages—$1.00—American Nature Association.

This handbook of Nature Education is a useful guide for those interested in nature study. A 24-page nature calendar offers much suggestive material. 80 pages are devoted to various nature associations and clubs, including a list of the science museums in the United States. Training nature educators and a survey of nature education take 160 pages. The book is concluded with a valuable nature bibliography.

The Earth and Its History—John H. Bradley—414 pages—257 illustrations—$2.60—Ginn and Company.

This is an excellent text for a short college course for beginners in Geology. It is written in a narrative style and gives a cultural rather than a technical point of view.

The chapter titles are: "The Earth as It Appears Today;" "Surface Processes of Destruction;" "Surface Processes of Construction;" "Subterranean Processes of Deformation;" "Rocks and the Architecture of the Earth;" "Geological Time and the Evolution of the Continents;" "Fossils and the History of Life on Earth;" "The Growth of Knowledge of the Earth;" "Geology in the Service of Man."

Mathematics for Agriculture and Elementary Science—H. B. Roe—David Eugene Smith and W. D. Reeve—354 pages—$2.80—Ginn and Company.

This is a college text giving the mathematics needed in Elementary college Science, particularly for students in Agriculture and Forestry. It presupposes high school Algebra and Plane Geometry, which are, however, briefly reviewed here. We find such practical topics as: Graphs; Statistics and Averages; Investments; Dairy Problems; Farm Management; Mensuration and Agricultural Engineering.

Our Surroundings—A. G. Clement, M. C. Collister and E. L. Thurston—628 pages—illustrated—Iroquois Publishing Company.

Here is still another attractive text in General Science added to our long and ever-increasing list. It begins with "The Meaning of Science" and passes on to a consideration of "Matter and Energy" and then to "Composition of Matter," thus giving a foundation in science for the chapters which follow. This is an excellent idea, but not generally practised in other texts. The remaining chapters follow in much the usual run of the more recent texts, but it may be said that it is particularly strong on the biological side of the subject. The first half of the book is Physical General Science and the last half is Biological General Science. There are six groups of very helpful general thought questions. One chapter is devoted to famous scientists. A helpful glossary ends the volume.

Handbook of Chemistry and Physics—Twelfth edition—Hodgman and Lange—1112 pages—flexible leather covers—$5.00—Chemical Rubber Publishing Company, Cleveland.

This ready reference of chemical and physical data should be on every Science teacher's desk and on the student's reference shelves. Unusual questions of fact not given in the text continually arise. You often wish tabulated data about properties and behavior of material under various conditions. Conversion tables, constants, heat of formation, viscosity, index of refraction, wave lengths, velocity co-efficients, formulas and definitions, are but samples of the multitude of material you will find here. There is a good index. The price to teachers and students is $2.50.

Food and Nutrition—Ruth Wheeler—123 pages—illustrated—paper covers, 60c; cloth, $1.00—P. Blakiston's Son and Company.

This is the American Red Cross textbook and takes up a study of the basis of food selection. It deals with: Nutrition and health; digestion; the factors of an adequate diet; food combinations; choice of food for people of different ages; variation in food requirements with state of health.

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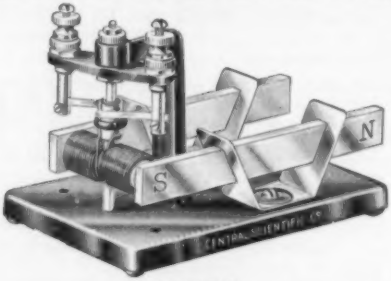

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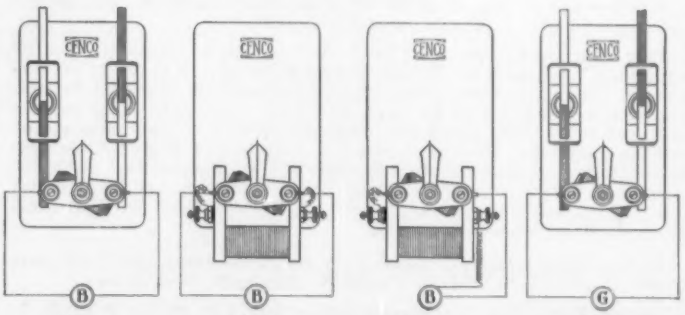

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Elementary Science—Gerald S. Craig—three paper-covered booklets—80 cents—Bureau of Publication, Teachers College, N. Y. C.

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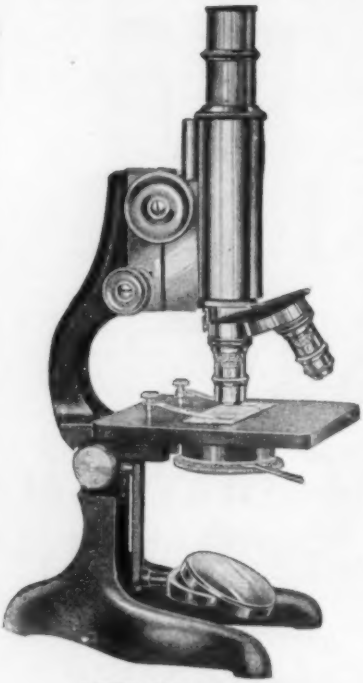

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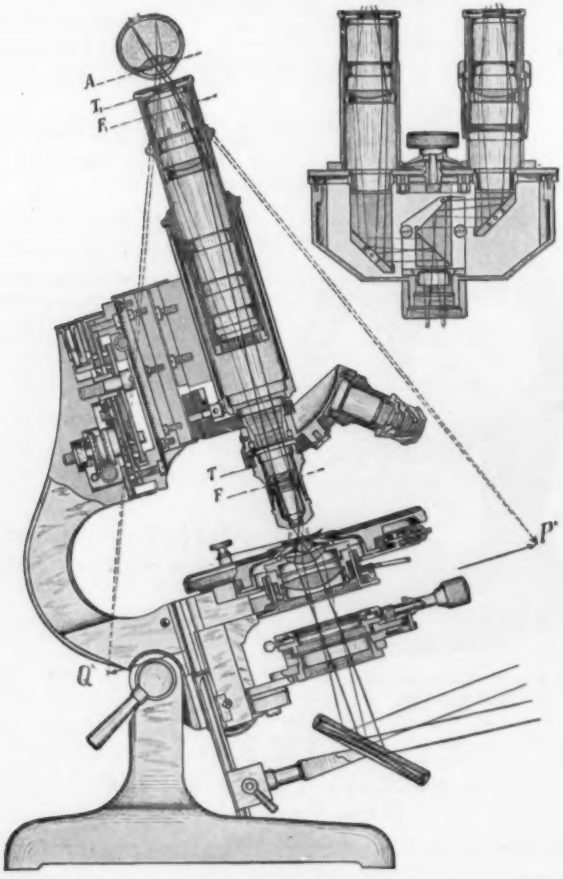
Science teachers were among the first to recognize the value of visual education, but often find it difficult to obtain proper materials for making full use of the sense of sight in the educative process, or cannot find time to assemble the materials. Many have tried to correlate demonstration lectures and providing extra work for the superior student by having students prepare the demonstration. Sometimes this works well, but often it requires more of the teacher's



time than if she prepared the demonstration herself. Below we offer two suggestions which may be used either in class or in the science club. The first has the double value of providing a good project for the bright student who wants to prepare an illustrated talk for class or club and of promoting vocational education. The second is a teaching device for presenting a difficult topic, and may be used for daily study after it has been explained in class or club.

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This is the title of a new bulletin issued by the Carnegie Institute of Technology in Pittsburgh. The author of the contents is William E. Mott, director of the College of Engineering. In connection with the bulletin, sets of stereopticon slides have been prepared to illustrate the points emphasized in the contents. Copies of the bulletin or sets of slides, or both, it is announced, will be sent to any high school or educational groups interested, for presentation before groups of interested students, by applying to Alan Bright, Registrar, Carnegie Institute of Technology, Pittsburgh, Pa.

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General Science Quarterly. Salem, Mass. Quarterly. 40c a copy, $1.50 a year. The only journal published devoted alone to science in the elementary and secondary schools. It tells what schools are doing in science, gives lesson plans, demonstrations, and an extensive bibliography of usable articles in current periodicals.

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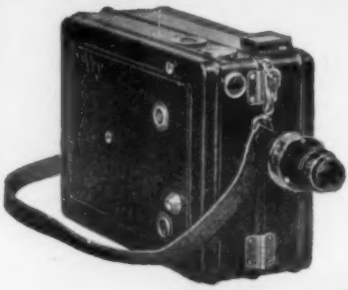

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Transactions of the Illuminating Engineering Society. 29 West 39th Street, New York. Monthly. $1.00 a copy, $7.50 a year. Technical. Many articles contain material which can be used in high school classes.